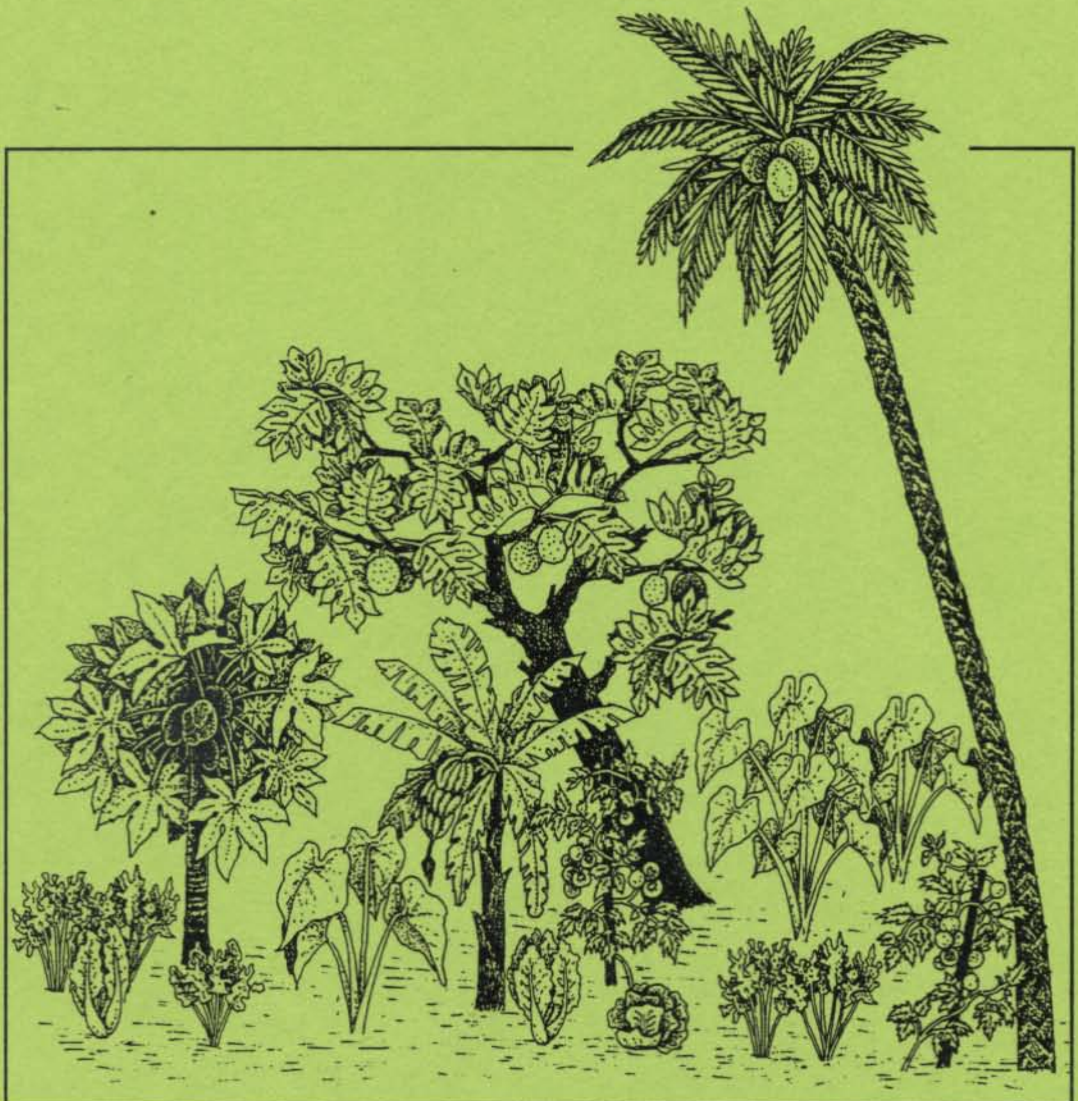
Agriculture Instructional Materials
ADAP 94-7

Crop Production for Pacific Islands

Instructor Manual



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Crop Production For Pacific Islands - Instructor Manual

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Crop Production for Pacific Islands

Instructor Manual

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Crop Ecology

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Crop Ecology 1

Performance Objectives

Upon completion of this chapter each student should be able to:

A. Define the 24 terms related to crop ecology.

B. Explain the three steps in the process of ecological succession.

C. Describe the forest/plant communities found on the student's home island including locations and some dominant species.

E. Explain the relationship between adaptation, niches, habitats, and competition; for plants growing in a natural ecosystem and also in an agroecosystem.

F. Explain the relationship between energy flow and nutrient cycling in natural ecosystems and agroecosystems.

G. Describe the differences in nutrient cycling between tropical and temperate ecosystems.

H. Describe the goal of agroecosystem management and the means of accomplishing the goal.

I. Explain the difference between biomass and yield.

J. Give at least three examples of how soil resources can be damaged by agroecosystem imbalances.

K. Give at least three examples of how water resources can be damaged by agroecosystem imbalances.

L. Give at least two examples of how food webs can be damaged by agroecosystem imbalances.

M. Identify crop production practices that can reduce damages caused by agroecosystem imbalances.

Terms

ADAPTATION- Changes in a species over time that allow it to better meet the needs of the environment.

AGROECOSYSTEM- Managed populations or communities of harvestable crops, together with all of the organisms and environmental factors influencing them.

ATOLL- A coral reef resting on a volcanic island base that usually has brackish ground water and limited mineral soil.

BIOMASS- The weight of all organisms in a given area that is measured to determine ecological productivity and efficiency.

BIOTIC COMMUNITY- The living parts of an ecosystem.

BRACKISH WATER- Salt and fresh water mixed together.

CLIMAX COMMUNITY- The species that exist at the final stage of ecological succession.

COMPETITION- The condition that exists when a limited supply of resources are required by more than one organism.

ECOLOGICAL BALANCE- The condition that exists when limited resources are conserved and the biotic community returns as much to the environment as it removes.

ECOLOGICAL DIVERSITY - A measure of the number of different species in an ecosystem.

ECOLOGICAL STABILITY- A measure of ecological balance despite moderate changes in the physical environment (temperature, light, moisture) or increased pressure due to pests or diseases.

ECOLOGICAL SUCCESSION- The process of changes in numbers and types of species within an ecosystem over time, that leads to a climax community.

ECOSYSTEM- All living and nonliving things in a given area that operate together through interaction and interdependence, forming a single unit.

ENVIRONMENT- The nonliving parts of an ecosystem.

EROSION- The movement of soil particles by wind or water.

ESTUARY- A location where fresh and saltwater mix.

HABITAT- The place an organism lives in the ecosystem.

LEACHING- The downward movement of nutrients through the soil.

MONOCULTURE- An agricultural system that produces only a single crop species.

NICHE- The functional role of an organism in an ecosystem.

NUTRIENT CYCLING- The movement of nutrients over time from an environment to organisms and back to the environment.

STRAND- The vegetation growing closest to the ocean, usually vines growing on sand or grasses in rocks.

VEGETATION INVENTORY- A study of the plant resources of a specific area.

YIELD- The weight or volume of a harvested crop.

I. Ecological Foundations

A. Review

1. **What is an ecosystem?**

Review the last chapter of *Plant Science for Pacific Islands.*

a. An ECOSYSTEM is all of the living and nonliving things in a given area that operate together through interaction and interdependence.

b. The ecosystem concept describes a functional unit that is more than the sum of its parts. It provides a framework of guiding principles to study natural and man-made systems.

c. The size, location, and number of components in an ecosystem are flexible. A continental mountain range, Pacific island, mangrove swamp, or a crop field can all be studied as an ecosystem.

2. **What are the rules of ecological succession?**

a. ECOLOGICAL SUCCESSION is the process of changes in numbers and types of species within an ecosystem over time, that leads to a CLIMAX COMMUNITY.

b. It results from changes in the ENVIRONMENT by the community, although the environment also limits what community can exist.

c. It ends in an ecosystem which has the greatest BIOMASS, DIVERSITY and STABILITY possible within the given environment.

B. Pacific Island Ecosystems

1. **How has ecological succession occurred on Pacific Islands?**

SA

Study materials on the native and introduced plants on your island.

a. Primary succession began on volcanic rock and/or coral sand.

b. Most Pacific islands in the humid tropics have developed into rainforest ecosystems.

c. The successional process resulted in conditions habitable by people.

d. Human actions including; clearing, tree harvest, introduced species, agriculture, and urban development have greatly impacted the forest communities of many Pacific islands.

e. Even in locations where the original rainforest ecosystems have been extremely altered, the successional communities and environment affect present day uses.

2. What types of forest communities are currently found in Pacific islands?

a. A VEGETATION INVENTORY is a study of the plant resources of a specific area that often contains maps, tables, graphs and text.

i. It describes the forest communities and plant species in generalized locations.

ii. The inventory is used for management and conservation purposes.

b. Most islands or political entities within the American Pacific have a vegetation inventory completed by the USDA Forest Service.

The plant communities described below represent major forest types identified by the inventories conducted in the region.

i. UPLAND FOREST- The native rainforest which covers most volcanic Pacific islands.

ii. SECONDARY FOREST- An area where the original tree species were cleared and enough time has passed to allow succession to reforest the land.

- Secondary forests are clearly different from upland forests because the trees which grow back do not form the same community as the original climax forest.

iii. AGROFOREST- An area of upland or secondary forest containing a mixture of food bearing plants with an uneven canopy and small clearings for taro and yam patches.

Forest Communities	American Samoa	Hawaii	No. Marianas	Kosrae	Palau	Ponpei	Truk	Yap
Upland Forest	*	*		*	*	*	*	*
Secondary Forest	*	*	*	*	*	*	*	*
Agroforest	*	*	*	*	*	*	*	*
Mangrove Forest	*		*	*	*	*	*	*
Coastal Forest	*	*	*			*		
Atoll Forest			*		*	*	*	*
Moss (Dwarf) Forest	*	*		*		*		
Swamp Forest				*	*	*		*
Plantation Forest		*			*	*	*	
Limestone Forest			*		*			
Palm Forest						*	*	

Overhead transparency of Plant Communities of Pacific Islands.

iv. MANGROVE FOREST- A tree covered area found in wet places at the mouth of streams and the edge of lagoons or saltwater marshes. An ESTUARY is a place where fresh and saltwater mix.

v. COASTAL FOREST- A tree covered area growing between the strand and other forest types. Trees are commonly salt tolerant with water dispersed seeds. STRAND is the vegetation closest to the ocean, usually vines growing on sand or grasses in rocks.

SA

Use the vegetation inventory for your area to study the locations and components of local forest communities

vi. ATOLL FOREST- Tree communities generally found toward the interior of uninhabited atolls that are similar to coastal forests.

An ATOLL is a coral reef resting on a volcanic island base that usually has brackish groundwater and limited mineral soil.

vi. MOSS (Dwarf)) FOREST- A community of stunted trees, ferns, mosses and orchids with an open canopy; located on cloudy mountain tops that are wet all year round..

C. Ecological Concepts and Crop Production

1. **How are adaptations, niches, and habitats related to crop production?**

a. Different types of organisms have specific growth requirements that are ADAPTATIONS to a particular set of environmental conditions.

b. A NICHE is the functional role an organism fills in an ecosystem, and a HABITAT is the place where an organism lives.

c. Crop production practices create habitats and niches to meet the physiological requirements (adaptations) of the target plant species.

- Orchids, cocoa, and coffee are given various amounts of shade to meet adaptations to growing below the forest canopy.

- Different taro cultivars require flooded or dry land conditions.

- Pineapple and sugarcane can not grow side by side unless irrigation is supplied for the cane crop because of their differing water needs.

2. **What is competition and how does it relate to crop production?**

a. COMPETITION occurs when a limited supply of resources (space, light, nutrients, water, and sometimes CO_2) are required by more than one organism.

- In the example above, pineapple and sugarcane grown side by side will compete for water and light. The morphology (form and structure) of each crop plays an important part in competition.

b. Agricultural niches and habitats are developed to manage intercrop competition Many crop production practices also reduce competition from pests including weeds, insects and diseases.

3. **How does energy flow relate to crop production?**

   a. The primary source of energy for natural ecosystems is the sun. Solar energy is used by plants to convert CO_2 to photosynthate.

   b. Photosynthate is the base supply of energy in a food chain. Food webs within a climax community are at an ecological balance.

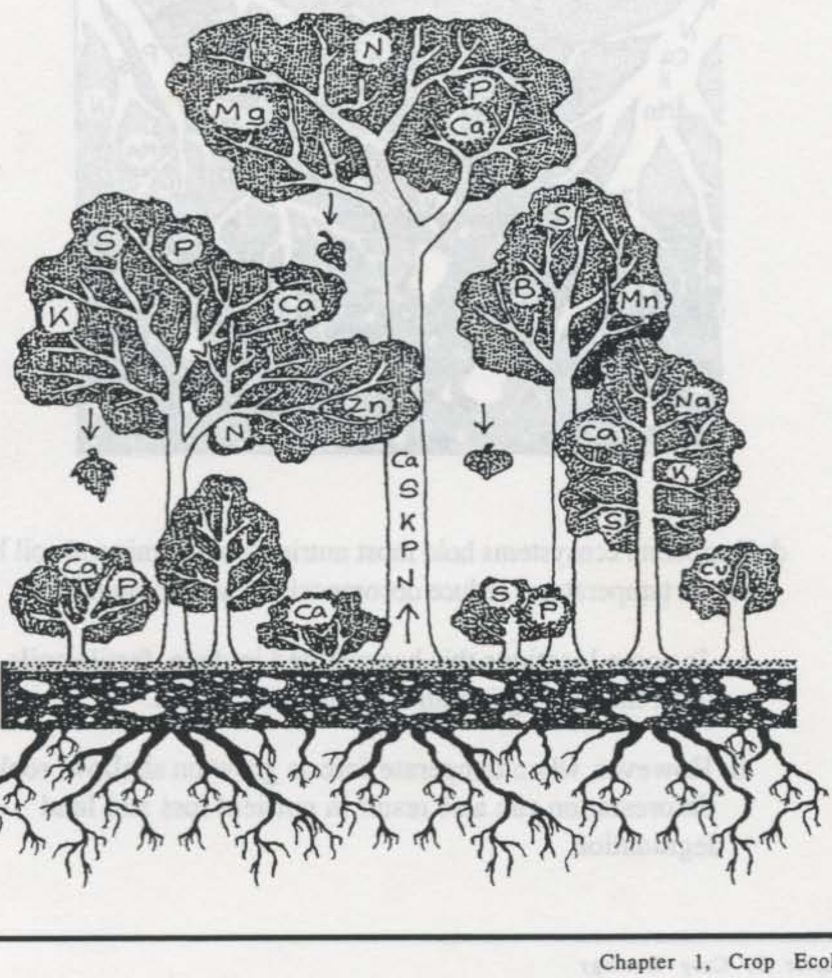
      ECOLOGICAL BALANCE is the condition that exists when limited resources are conserved and the biotic community returns as much to the environment as it removes.

   c. Crop production harvests are usually removed from agroecosystems. External energy inputs are needed to balance the system.

4. **How does nutrient cycling relate to crop production?**

   a. NUTRIENT CYCLING refers to the movement of nutrients over time from the environment to organisms and back to the environment.

   b. Nutrient cycling affects tropical and temperate ecosystems differently. These difference are very important in selecting appropriate crop production practices.

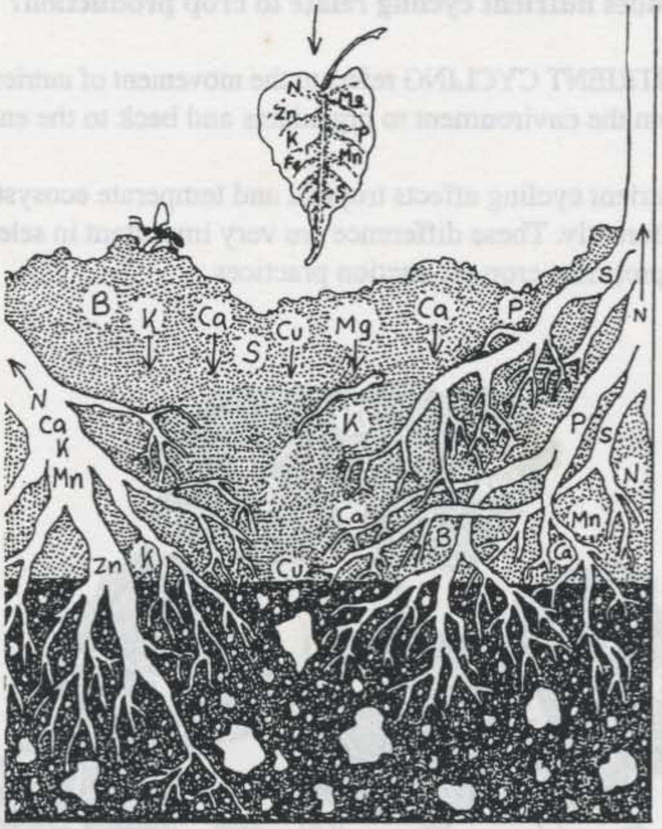


c. In tropical ecosystems nutrients are held primarily in the vegetation and in the soil organic matter which decompose quickly under conditions of high temperature and rainfall.

i. Nitrogen and phosphorus are often in very short supply and nutrient cycling is critical to maintaining a stable ecosystem.

ii. The removal of nutrients by deforestation and/or crop harvest can result in serious disruption of the system.

iii Tree clearing and crop cultivation can also cause erosion and quicken oxidation of organic matter resulting in rapid loss of ecosystem nutrients.



OPT

Discuss the symbiotic relationship of tree roots and soil fungi in tropical nutrient cycling systems.

d. Temperate ecosystems hold most nutrients in the mineral soil because cooler temperatures reduce decomposition and nutrient loss.

i. In some locations this has resulted in deep, fertile soils which form the best agricultural lands in the world.

ii. However, when temperate forests grow on shallow, rocky soil deforestation can also result in nutrient loss and land degradation.

II. Agroecosystems

A. Agroecosystem Concepts

1. What are agroecosystems?

a. AGROECOSYSTEMS are managed populations or communities of harvestable crops, together with all of the organisms and environmental factors influencing them.

b. All agroecosystems have a measurable level of diversity and stability, and an energy flow of inputs and outputs. The level of management determines the location of an agroecosystem within the spectrum of natural and man-made (urban areas) ecosystems.

2. Why are agroecosystems managed?

a. The goal of managing an agroecosystem is to maximize the yield from the cultivated species (crops) by providing essential inputs without producing unneeded (and potentially damaging) outputs.

YIELD is the amount of a crop harvested for use.

b. This is accomplished by creating a niche environment that is ideal for the cultivated species with an optimum of needed resources and minimum competition for those resources.

c. Reducing competition for the cultivated species by pest/diseases must also be managed at an optimum (economic threshold) level.

3. How is succession managed in different agroecosystems?

a. A multi-crop agroforestry system that produces food and fiber within a modified forest community contains a large degree of the diversity and stability found in a natural ecosystem. Only a limited management of succession is required.

b. A MONOCULTURE system that produces only a single crop species creates a very unstable community that must be highly managed. An ideal habitat (water, fertility, pest control) is established and maintained for the target species.

4. How is energy flow managed in different agroecosystems?

a. The primary source of energy input to most agroecosystems is the sun. However, because products (food and fiber) are removed at harvest and competition is managed, additional inputs are required.

i. Organic and inorganic materials are used to supplement the nutrient cycle.

ii. Energy inputs (human, animal, mechanical) are used to reduce competition from weeds, insects and diseases.

iii Larger amounts of fossil fuel energy are used as the level of mechanized, industrial agriculture is increased.

iv. Unstable systems are maintained by high levels of additional energy inputs (fertilizer, irrigation, pesticides, etc.).

b. A high level of energy inputs to an agroecosystem must result in increased outputs. Some of these outputs are the intended high yield of agricultural products, but others are waste materials that may have damaging effects.

B. Agroecosystem Imbalance

When the inputs and outputs of crop production are not in balance there is potential for damaging effects both within and outside the agroecosystem. These damages affect soil and water resources as well as plants, animals and people.

1. **How can soil resources be damaged by imbalances?**

a. Chemical salts that remain in the ground after numerous fertilizer applications may damage the soil chemistry and limit plant growth.

b. When fertility management inputs are limited, nutrients may become severely depleted by crop yields, leaching, and erosion.

LEACHING is the downward movement of nutrients through the soil.

c. EROSION is the movement of soil by wind and water. If topsoil eroded from crop fields is not replaced by organic material from cultural practices, only the poor quality subsoil is left for farming.

Study examples of local agroecosystem imbalances.

Discuss crop production practices that can prevent the imbalances.

2. **How can water resources be damaged by imbalances?**

a. Eroded soils can carry agricultural pollution into streams and drinking water reservoirs.

b. Pesticides can poison groundwater, surface streams and aquatic organisms if used or disposed of improperly.

c. Fertilizers may also pollute groundwater aquifers or increase aquatic plant growth in streams and lagoons.

3. **How can food webs be damaged by imbalances?**

a. The proper management of competition from pests and diseases requires a detailed understanding of food webs in the agroecosystem. Adding or removing a species often creates unintended damage.

b. Removal of predators can create uncontrollable outbreaks of insects and diseases

c. Introduced predators without any natural controls can become pest problems themselves.

Crops and Climates 2

Performance Objectives

Upon completion of this chapter each student should be able to:

A. Define the 55 terms related to crops and climates

B. Explain the difference between weather and climate.

C. Define the four basic elements of climate change.

D. Describe the four primary factors that affect the elements of climate.

E. Explain how quantity and quality of light are measured.

F.. Explain the effects of latitude on daylength and light intensity for areas close to the equator.

G. Name and explain four ways light affects plants.

H. Explain how flowering and modified stem growth can be affected by daylength.

I. Explain the differences between C3, C4, and CAM plants.

J. Explain four ways crops can be manipulated to optimize light interception.

K. Determine the crop density of a planting area.

L. Convert temperature measurements between the Fahrenheit and Celsius scales.

M. Explain four factors that affect temperatures in different locations.

N. Describe three processes of heat transfer.

O. Explain at least four factors that affect temperatures in different locations.

P. Describe four plant responses to cooler temperatures.

Q. Explain three ways plants reduce high temperature stress.

R. Describe three ways that quantity of precipitation is measured and how these affect crop production.

S. Explain seven ways water affects plants.

Crops and Climates

2

Terms

ABSORPTION SPECTRUM- The various wavelengths of light that are absorbed by a plant part or pigment.

ALTITUDE- The vertical elevation of an object or area above sea level.

ASPECT- The position (or side) of a slope facing a particular direction.

BRITISH THERMAL UNIT (BTU)- The amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

CALORIE (cal)- The amount of heat required to raise the temperature of 1 gram of water by one degree Celsius.

CELSIUS SCALE (C)- The measurement of temperature in which zero degrees is the freezing point of water and 100 degrees is the boiling point.

CHILLING REQUIREMENT- The number of hours below a given specific temperature required for buds to break dormancy.

CLIMATE- A description of the weather conditions commonly found in a region over time.

CONDUCTION- The flow of heat through a substance.

CONTOUR PLANTING- The practice of cultivating and planting land along lines of equal elevation to reduce soil and nutrient erosion.

CONVECTION- The transfer of heat by a moving fluid or gas.

CONVERGENCE ZONES- Areas between 10 degrees north and 10 degrees south latitude that develop accumulated clouds and gusting winds created by changes between the air and water temperatures.

CROP DENSITY- The relationship between the quantity of plants and the size of the planting area.

DAY LENGTH- The amount of time between sunrise and sunset.

ELECTROMAGNETIC SPECTRUM- The range of radiant energy from wavelengths of less than 0.001nm (cosmic and gamma rays) to greater than 100,000 nm (radio waves).

ETIOLATION- The effect of insufficient light, which causes a plant to grow a long, thin stem and small leaves.

FAHRENHEIT SCALE (F)- The measurement of temperature in which 32 degrees is the freezing point of water and 212 degrees is the boiling point.

GREENHOUSE EFFECT- The absorption and retention of solar radiation by the Earth's atmosphere.

HARDENING OFF- The treatment of tender plants to help them to survive in a more adverse environment.

HEAT- A form of energy that increases the temperature of a body of matter when it is transferred, so long as the body of matter does not change state, (water to ice, water to steam, etc.).

HUMIDITY- Water vaporized in the air.

INFILTRATION RATE- The maximum speed at which water can enter the soil under specific conditions.

INSOLATION- The solar radiation that reaches the Earth's surface.

IRRIGATION- The application of water to a crop or area of soil by means other than natural rainfall.

IRRADIANCE- The amount of sunlight falling on a unit area of surface.

KNOT- A nautical speed measurement equal to 1.15 miles per hour.

LATITUDE- The angular distance of a location north or south of the equator, measured in degrees.

LEAF AREA INDEX (LAI)- The leaf surface area over a unit area of soil.

LEAF ORIENTATION- The arrangement of leaves in space with reference to an axis (line) perpendicular to the ground.

LIGHT- The portion of the electromagnetic spectrum (400 to700 nm) that can be seen by the human eye.

LIGHT COMPENSATION POINT- The level of irradiance at which the amount of CO_2 being fixed by photosynthesis equals the amount lost in respiration.

LIGHT SATURATION LEVEL-The point where CO_2 becomes the limiting factor in increased photosynthesis.

LUMEN (lm)- The amount of light from a standard candle onto an area one foot square. This measure is also referred to as a footcandle (fc).

MICROCLIMATES- The atmospheric conditions of relatively small areas that differ significantly from those in surrounding region.

MONSOON- Conditions that create a climate that is very dry during most of the year followed by extremely heavy precipitation in the rainy season.

MULCH- Any material that is spread over the soil surface to control erosion and/or weed growth.

PHOTOPERIODISM- The developmental response of plants to the length of the light and dark periods of a day.

PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR)- That fraction of the solar spectrum where quanta have sufficient energy to drive the photosynthetic process.

PRECIPITATION- Condensed water vapor that falls from the sky as rain, hail, or snow.

PRUNING- The removal of plant parts to maintian a desirable form by controlling the direction and amount of growth.

QUANTA- The discreet unit of light energy absorbed by pigment molecules such as chlorophyll.

RADIATION- The flow or transfer of energy without any connecting medium.

RELATIVE HUMIDITY- The ratio of the weight of water vapor in a given quantity of air to the total weight of water vapor that quantity of air is capable of holding at a given temperature.

SOIL CONSERVATION- The wise use of land resources through a combination of appropriate practices.

STRATIFICATION- The process of breaking seed dormancy by cold treatment.

SUNLIGHT- Solar radiation; the ultimate source of almost all energy on Earth.

TEMPERATURE- A measure of the intensity of heat in a body of matter.

THERMOPERIODISM- The need for alternating warm and cool temperatures to influence flowering and/or vegetative growth.

TRADE WIND- A seasonal pattern of air movement toward the equator that is found in the tropics.

VERNALIZATION- The induction of flowering by exposure to cool temperatures.

WATER POTENTIAL- The tendency of water molecules to diffuse, evaporate or be absorbed from one area to another.

WATER STRESS- The condition that occurs in plants when water loss exceeds water uptake, causing a reduction in leaf water content.

WEATHER- The state of the atmosphere at a given place and time.

WIND- The natural or artificially induced movement of air.

WINDBREAK- A planting of trees and/or tall perennials used to deflect air movement around crops, land, and structures to be protected.

I. Introduction

1. **What is the difference between weather and climate?**

   a. WEATHER is the state of the atmosphere at a given place and time. It is affected by the four basic elements listed below. Changes in these elements result in changes in the weather.

   b. CLIMATE is a description of the weather conditions commonly found in a region over time. For example, tropical regions have climates clearly different from those found in the polar and temperate regions of the world.

2. **What are microclimates?**

   a. MICROCLIMATES are the atmospheric conditions of relatively small areas that differ significantly from those in the surrounding region. For example, Pacific islands which have mountainous areas will contain a range of microclimates between the mountain tops and the shoreline. Opposite sides of a valley often have different microclimates.

3. **What are the four basic elements of weather and climate?**

   a. LIGHT is the portion of the electromagnetic spectrum (from 400 to 700 nm) that can be seen by the human eye.

   b. TEMPERATURE is a measure of the intensity of heat in a body of matter.

   c. PRECIPITATION is condensed water vapor that falls from the sky as rain, hail, or snow.

   d. WIND is the natural or artificially induced movement of air.

4. **What are the primary factors that determine the climate of a specific place?**

   a. LATITUDE is the angular distance of a location north or south of the equator, measured in degrees.

   b. ALTITUDE is the vertical elevation of an object or area above sea level.

   c. Nearness to large bodies of water

   d. Nearness to hills or mountains

A globe will be useful in the study of lattitude, insolation and temperature.

II. Climatic Elements Affecting Plant Growth

A. Light

1. How is light measured?

a. Quantity

i. LUMEN (lm) = The amount of light from a standard candle onto an area one foot square. This measure is also referred to as a footcandle (fc).

- Full sunlight at noon is about 1,080 lm.
- Enough light for reading is about 20 lm.
- Full moonlight is about 0.03 lm.

b. Quality

i. Light is a form of electromagnetic energy that is classified on the basis of distance between waves (length) and the speed of waves passing a point in a given period of time (frequency).

The ELECTROMAGNETIC SPECTRUM contains all wavelengths from very long infrared waves to extremely short x-ray waves. In between these is the visible part of the spectrum composed of the all the portions which the human eye can see as colors, called light.

Light quality can vary depending on the source. An incandescent light has a different spectrum than a fluorescent light and both are different—and less useful to plants—than sunlight.

ii. SUNLIGHT is solar radiation; the ultimate source of almost all energy consumed on Earth, especially the energy consumed by living things.

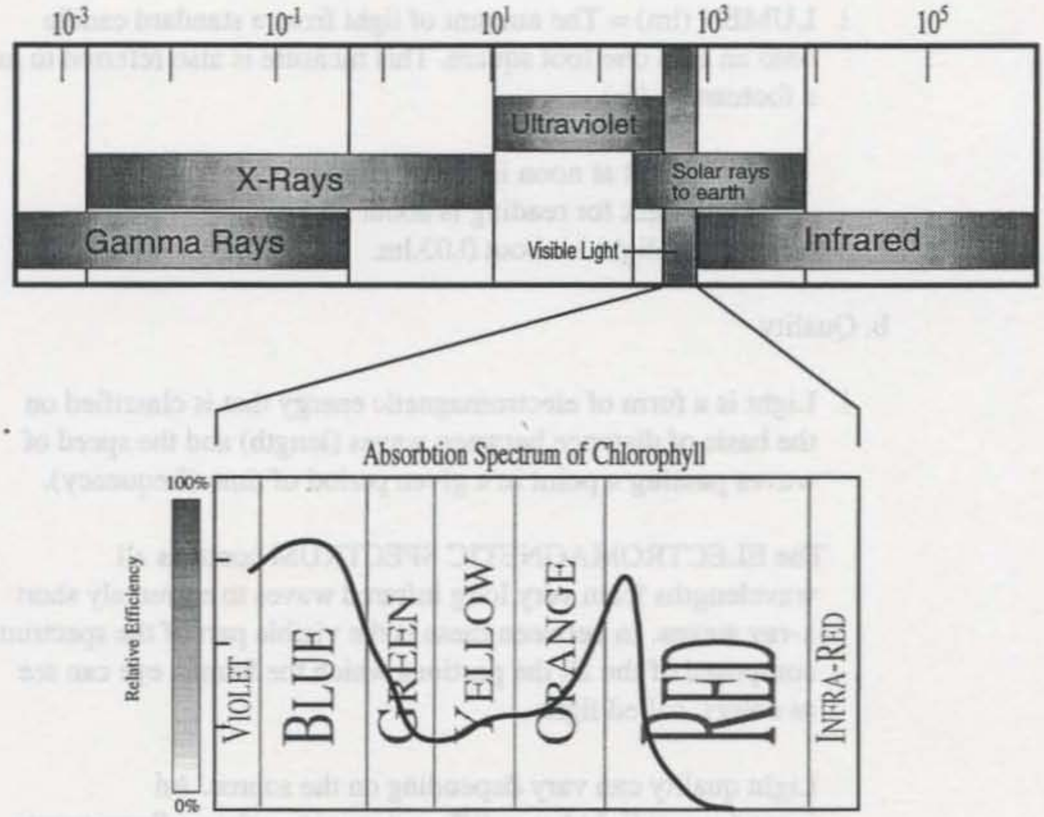
INSOLATION is the solar radiation that reaches the Earth's surface. The amount of insolation is small compared to total energy output of the sun. A large amount of all solar radiation is reflected back to space by clouds in the atmosphere.

SA

Review photosynthesis in *Plant Science for Pacific Islands.*

Insolation is the part of solar radiation that affects life on Earth, especially plants. Chlorophyll is the pigment in plants that absorbs light for PHOTOSYNTHESIS. Photosynthesis is the process of changing light energy into chemical energy (which can then be stored for later use).

Show electromagnetic spectrum diagram with overhead projector.



iii. The ABSORPTION SPECTRUM of a pigment indicates its ability to absorb light of specific wavelengths. Chlorophyll has an absorption peak in the blue-violet region and a second, smaller peak in the red region of the spectrum.

SA

Lab experiment on chlorophyll extraction.

SO WHY DOES A LEAF LOOK GREEN? This is because most red and blue-violet portions of the light are absorbed by chlorophyll. A smaller amount of the green and yellow are absorbed with the balance reflected back to the eye.

2. **What factors affect the degree of insolation reaching different locations?**

a. Insolation decreases as latitude increases (moving away from the equator). The equator is zero degrees latitude.

i. The same amount of solar radiation is spread over a larger area at locations closer to the poles,

ii. The depth of the atmosphere increases; which absorbs, reflects and scatters the sunlight; reducing insolation.

b. DAY LENGTH is the amount of time between sunrise and sunset. At the equator day length is 12 hours at all times of the year. At locations north or south of the equator summer day length increases and winter day length is shorter. These changes are in direct proportion to distance from the equator. At the extreme polar regions summer day length will be 24 hours long and winter days will have no sunlight.

Transparency showing the effect of latitude and season on day length.

The Effect of Latitude and Season on Daylength

Latitude, °N	*Mar 21*	*June 21*	*Sept 21*	*Dec 21*
0	12 hours	12 hours	12 hours	12 hours
10	12 hours	12 h, 35 min	12 hours	11 h, 25 min
20	12 hours	13 h, 12 min	12 hours	10 h, 48 min
30	12 hours	13 h, 56 min	12 hours	10 h, 4 min
40	12 hours	14 h, 52 min	12 hours	9 h, 8 min
50	12 hours	16 h, 18 min	12 hours	7h, 42 min
60	12 hours	18 h, 27 min	12 hours	5h, 33 min
70	12 hours	Two months	12 hours	No daylight
80	12 hours	Four months	12 hours	No daylight
90	12 hours	Six months	12 hours	No daylight

3. **How does light affects plants?**

a. Photosynthesis. Only a small amount (2-4%) of the sunlight striking a leaf is absorbed for use in photosynthesis. The rest must be disposed of through evapotranspiration and heat transfer.

PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR) is that fraction of the solar spectrum where quanta have sufficient energy to drive the photosynthetic process.

As the intensity of PAR increases, photosynthesis begins and increases until the LIGHT COMPENSATION POINT is reached. The light compensation point occurs when the amount of CO_2 being fixed by photosynthesis equals the amount being lost in respiration.

Beyond this point photosynthesis will increase rapidly with increasing PAR, until the LIGHT SATURATION LEVEL is reached. The light saturation level occurs when photosynthesis is limited by some other factor.

b. PHOTOPERIODISM is the developmental response of plants to the length of the light and dark periods of a day. Although the terms refer to day length, research has shown it is actually the length of the dark period that is critical. Photoperiodism can affect flowering, growth of modified stems, bud dormancy, and leaf abscission.

SA

Lab experiment on seedling growth.

i. Flowering can be triggered when day length is shorter than some critical period in "short day plants". Poinsettia is a common short day plant. Flowering can also be triggered when day length is longer than a given critical period in "long day plants". The potato is an example of a long day plant.

ii. The production of modified stems such as tubers and bulbs is stimulated by a short photoperiod. The degree of control depends on the cultivars being grown. Breeding of potatoes and onions has produced cultivars that have no production problems close to the equator where photoperiod may have been inhibiting.

c. ETIOLATION is the effect of insufficient light which causes a plant to grow a long, thin stem and small leaves. This process is beneficial to seedlings pushing their way to sunlight. However, close spacing can also cause etiolation of crop plants which makes them weak and easy to fall over.

d. PHOTOTROPISM is a directional growth response to a directional light stimulus. When plants receive light from one direction they tend to bend toward the light. Phototropism is caused by higher concentration of growth hormone (auxin) on the shaded side, which elongates the cells causing the stem to bend.

4. **How have plants adapted to different light conditions?**

a. C3, C4 and CAM plants.

There are two primary photosynthetic pathways used by plants referred to as either C3 and C4. The first product of carbon dioxide has three carbons, thus the name C3 plant. In C4 plants, the first product of carbon dioxide fixation has four carbon atoms.

The C3 pathway is the most common and plants of this type become light saturated at about half of full sunlight levels. These plants are less efficient in fixation of CO_2 due to losses caused by photorespiration. Most of the world's crops are C3 plants, these include; soybeans, wheat, and rice.

C4 plants have developed a different leaf structure and photosynthetic pathway which allows them to overcome the inefficiency of C3 plants. Leaves of C4 plants are not light saturated at more than twice the level of C3 plants. They have greater production potential and can make use of available light up to full sunlight levels. These plant adaptations have been an advantage in high sunlight and temperature conditions. C4 plants are mostly tropical grasses and other plants found in hot and/or dry climates. A few of the most important C4 crops are sugarcane, corn, and sohrgum.

A different variation on photosynthesis is found in CAM (crassulâcean acid metabolism) plants. These plants fix the atmospheric CO_2 needed during the night. This adaptation allows CAM plants to keep their stomates closed during the heat of the day. Many CAM plants are cacti or succulents. One important crop plant is pineapple.

b. Sun Plants and Shade Plants

The classification of sun plants and shade plants is based upon the light level needed to saturate photosynthesis. The light saturation point of a plant is dependent on factors including the species, CO_2 concentration, and the environment under which each leaf has developed. Only C3 plants are shade tolerant.

Certain plants, which have adapted to heavily shaded conditions on the forest floor, may be light saturated at five percent of full sunlight, with very low rates of maximum photosynthesis. Sun plants generally require high light intensity to grow well.

As sun plants develop, the older leaves become shaded by new leaf growth. The older leaves must adapt to lower light levels and decrease their level of photosynthesis and respiration. Some shaded leaves may use more energy in respiration than they produce, and on many plants these leaves will die before becoming a liability.

SA

Lab on metric equations

SA

Lab on tree pruning

5. How can crops be manipulated to optimize light interception ?

a. Determine the crop density.

i. CROP DENSITY is the relationship between the quantity of plants and the size of the planting area.

ii. The optimum crop density will maximize the light intercepted by the plants. This is determined by the distance between rows, and the distance between plants in a row in relation to the total planted area.

Determining crop density

$$\text{Crop density} = \frac{\text{Total Area}}{(\text{Distance between rows}) \times (\text{Distance between plants})}$$

For example, what is the crop density per hectare if the crop is planted with 80cm between each row and 25cm between each plant?

$$\frac{10{,}000\text{m}^2 \text{ (1Ha)}}{.8\text{m x .25m}} = \frac{10{,}000\text{m}^2 \text{ (1Ha)}}{.2\text{m}^2} = \text{50,000 plants per hectare}$$

It is best to use the metric system when computing crop density with this formula

b. Eliminate light competition wherever possible.

i. Remove unnecessary shade produced by trees and plants close to crops.

ii. Reduce light competition within the crop canopy.

LEAF AREA INDEX (LAI) is the leaf surface area over a unit area of soil. The LAI varies with crop density, species, cultivar, stage of development, nutrition, available moisture and other factors. For most crops there is a range of LAI where yields level off and then begin to decline from light competition. As a general rule a LAI between four and eight is optimal.

EXAMPLE: If the average leaf surface area in a taro plantation is 5 square meters over any chosen square meter of ground, then the LAI is 5.

PRUNING is the removal of plant parts to maintain a desirable form by controlling the direction and amount of growth. In tree crops the light level in the canopy is controlled by pruning. Heavy shade within the canopy often suppresses flower bud formation, fruit set, and fruit size.

c. Reduce weed competition by limiting available light.

i. Establish the crop canopy fast to shade out weeds.

ii. For slower growing plants, use a nursery where seedlings can be grown until transplant time.

iii. Use mulch to shade soil and prevent weed growth.

d. Match the crop to the light conditions available.

i. Grow shade tolerant crops below sun loving crops.
ii. Grow plants to protect shade loving crops.
iii Construct shade structures for propagation/nursery areas.
iv. Harden plant to full light conditions before transplanting.

B. Temperature

1. How is temperature measured?

a. Quantity

i. The common U.S. measurement of temperature has been the FAHRENHEIT SCALE (F), in which 32 degrees is the freezing point of water and 212 degrees is the boiling point. That scale is slowly being replaced by the metric system's CELSIUS SCALE (C). In Celcius measurements, zero degrees is the freezing point of water and 100 degrees is boiling point.

SA

Lab exercise on temperature conversions

Converting temperatures between the Celsius and Fahrenheit systems

° Fahrenheit= 9/5 °C+32

° Celsius= 5/9 (°F-32)

ii. HEAT is a form of energy that increases the temperature of a body of matter when it is transferred, so long as the body of matter does not change state, (water to ice, water to steam, etc).

iii Heat energy is measured in CALORIES or BRITISH THERMAL UNITS. A CALORIE (cal) is the amount of heat required to raise the temperature of one gram of water by one degree Celsius. A British thermal unit (BTU) is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

b. Quality

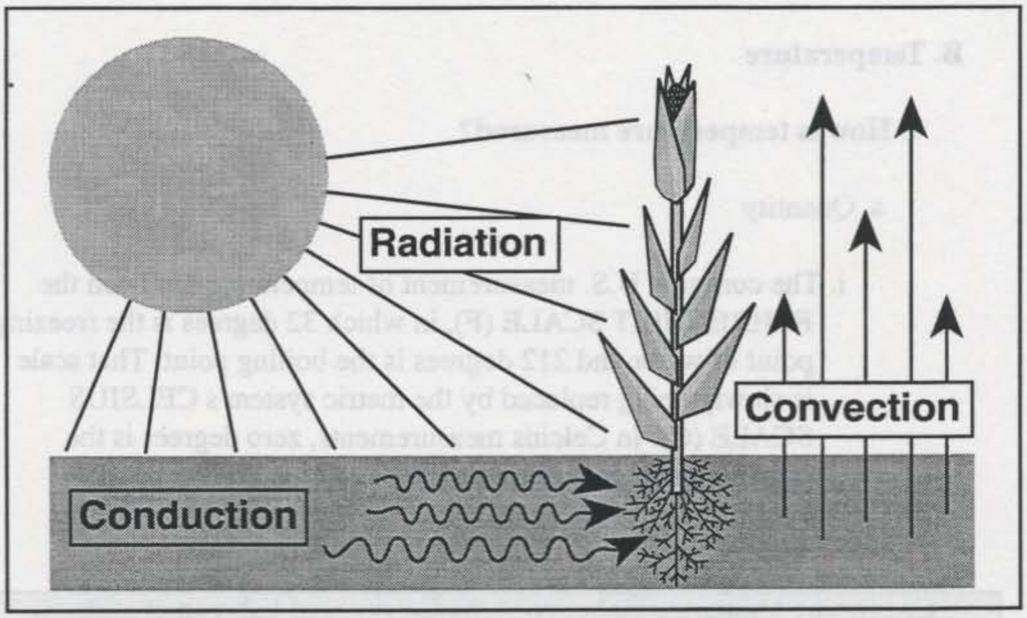
The transfer of heat can occur by three different processes, and the transfer of energy is always from the warmer to the cooler body of matter:

RADIATION is the flow or transfer of energy without any connecting medium. Solar radiation is an example of this process.

CONDUCTION is the flow of heat through a substance. An example of this process is the flow of heat from soil to the roots of a plant.

CONVECTION is the transfer of heat by a moving agent, for example the transfer of heat from soil to air above it.

Transparency of the heat transfer process.

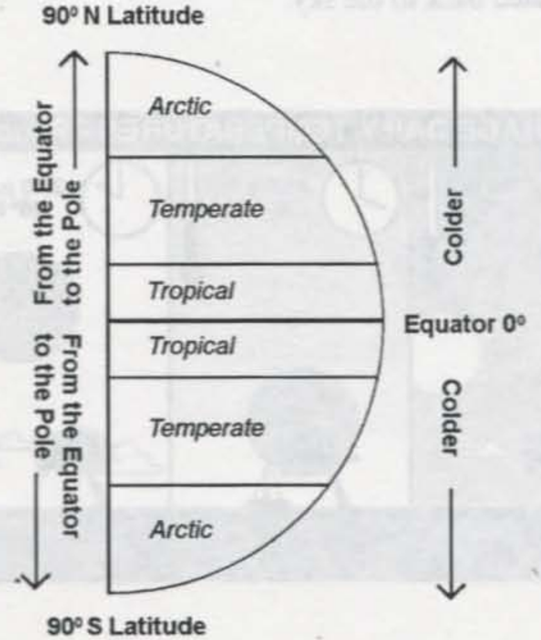


2. **What factors affect temperatures in different locations?**

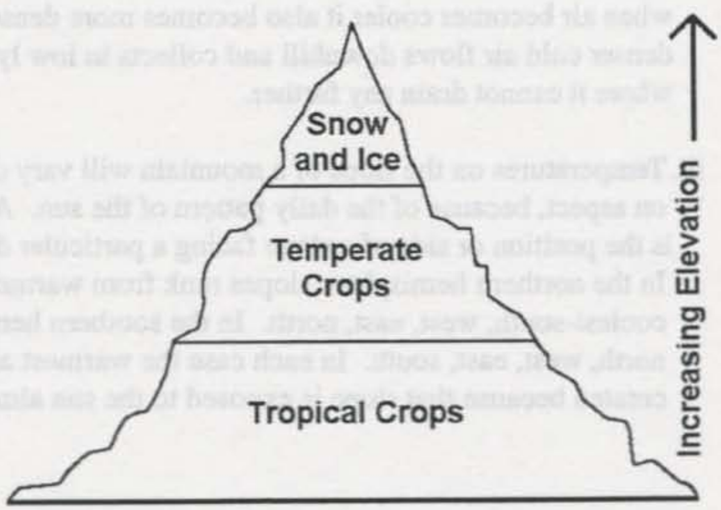
Solar insolation is the primary source of heat on Earth. The daily and annual changes in temperature that occur are directly related to the latitude, altitude, seasons, and other factors affecting the receipt and transfer of solar energy.

a. The rotation of the Earth around the sun changes the solar angle and day length. These factors create seasonal temperature patterns. The changes are minimal close to the equator and increase greatly at locations closer to the poles. Temperature patterns are exactly opposite between areas north and south of the equator (i.e. January is the coldest month in north and warmest month in the south).

b. The average annual temperatures are higher closer to the equator. Latitude affects temperature as a result of the higher solar angle and insolation at the equator, described earlier regarding light.

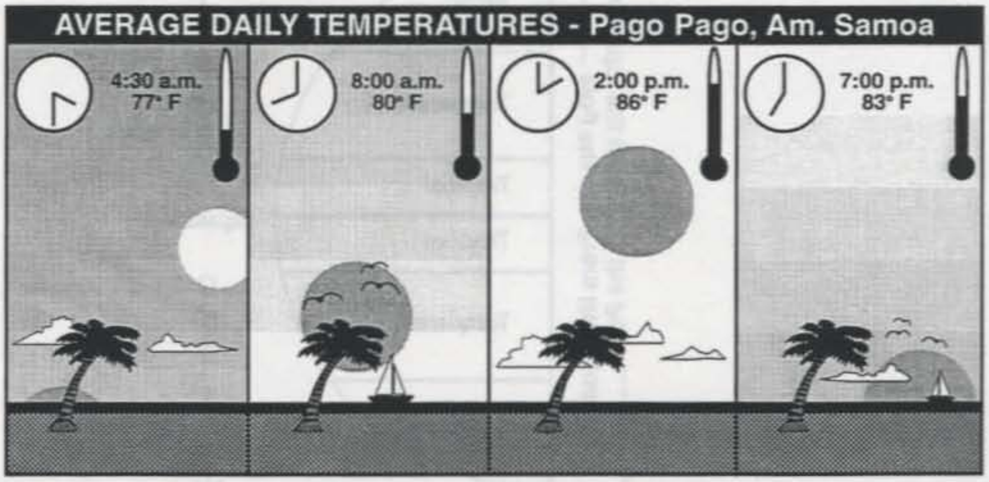


c. Temperature decreases with altitude, irrespective of latitude. Altitude is the vertical elevation of an object or area above sea level. For each 100 meters increase in elevation, the mean temperature of the location decreases by 0.6 degrees Celsius. In Hawaii—on Maui and the "Big Island"—tropical crops are grown at sea level and slightly above, some temperate crops are grown on the slopes, and the mountain tops are covered with snow during the winter months.



d. The time of day affects temperature at any given moment. Temperatures are highest at the point of maximum heat gain, usually about mid-afternoon. The lowest temperature occurs just before sunrise when most of the absorbed surface heat has been reradiated back to the sky.

Transparency of the effects of time of day on temperature.



e. Other factors including proximity to bodies of water and mountains affect the temperature in smaller, localized areas.

i. Because water stores more heat per unit volume and conducts heat better, it heats and cools more slowly than land. This tends to make temperature changes more gradual in areas close to water.

ii. Areas at the base of mountains and in valleys tend to be cooler at night than those elsewhere at the same elevation. At night when air becomes cooler it also becomes more dense. The denser cold air flows downhill and collects in low lying areas where it cannot drain any further.

iii. Temperatures on the slope of a mountain will vary depending on aspect, because of the daily pattern of the sun. ASPECT is the position or side of a slope facing a particular direction. In the northern hemisphere slopes rank from warmest to coolest-south, west, east, north. In the southern hemisphere-north, west, east, south. In each case the warmest aspect is created because that slope is exposed to the sun almost all day.

3. **What are the effects of temperature on plants?**

a. Through natural selection or breeding, species and cultivars have become adapted to different temperature requirements. These requirements can be summarized as the:

i. minimum temperature below which a plant cannot grow,
ii. maximum temperature above which a plant cannot grow, and
iii. the optimum temperature at which the plant grows best.

b. In the temperate part of the world successful cropping is dependent on temperatures high enough for plants to grow and complete their life cycle. In tropical regions cooler temperatures are sometimes needed to trigger certain responses in plants more commonly grown in other places.

i. CHILLING REQUIREMENT is the number of hours below a given specific temperature required for buds to break dormancy. This is why temperate fruit crops such as apples and peaches are not grown in low altitude tropics.

ii. VERNALIZATION is the induction of flowering by exposure to cool temperatures.

iii. STRATIFICATION is the process of breaking seed dormancy by cold treatment.

iv. THERMOPERIODISM is the need for alternating warm and cool temperatures to influence flowering and/or vegetative growth. For example, research has shown tomatoes grow more rapidly with an eight degree Celsius difference between day and night temperatures.

c. In the tropics the greatest concern is how plants reduce high temperature stress. A very small amount of insolation is used in photosynthesis and the remainder must be disposed of to keep the plant cool. There are three major plant strategies to accomplish this:

i. Evaporation is the means by which up to 80 percent of the energy falling on a leaf is dissipated. However when water stress causes stomata to close this process stops and temperatures may reach critical levels.

ii. Reflection of light is especially important to leaves in the canopy layer. Lighter colors are more reflective than dark green leaves.

iii. LEAF ORIENTATION determines the angle at which leaves present themselves to solar rays. Leaves that have a more vertical orientation receive enough radiation for photosynthesis while remaining cooler than leaves with horizontal orientation.

C. Precipitation and Water.

1. How is precipitation measured?

Activity: Field trip to a local weather station.

Lab Exercises-
- Use a rain gauge
- Study condensation
- Measure humidity
- Plot annual and monthly precipitation for different locations

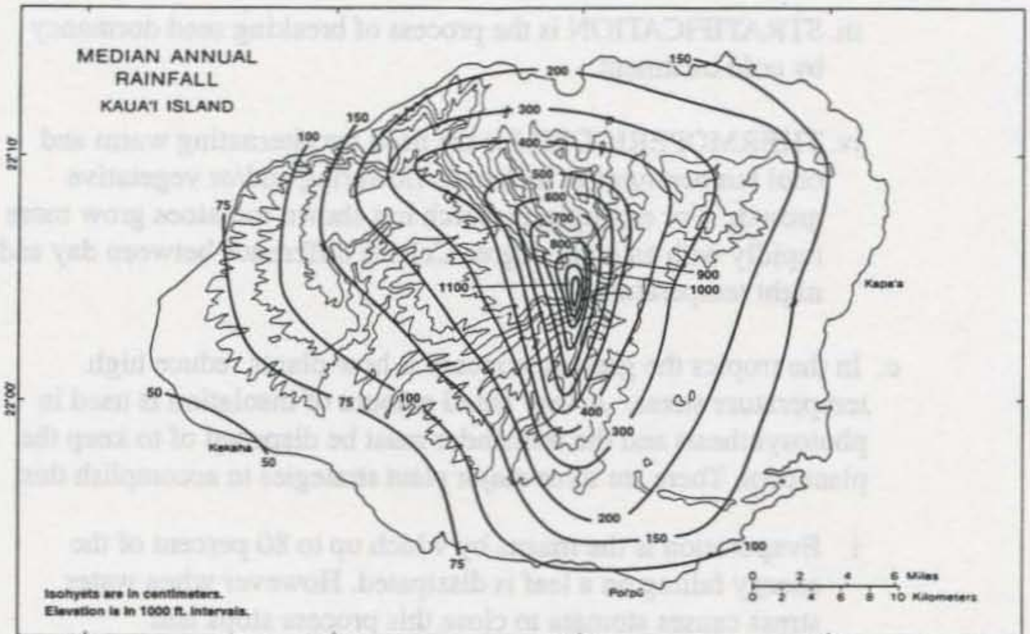
a. Quantity

The amount of precipitation at a location is generally measured in inches or centimeters over a period of time (annual, monthly, daily).

i. Annual Precipitation. The average annual precipitation for different parts of the world can range from less than one cm to over 1000 cm. Rainfall levels can be very different in places that are not far apart. This is quite common on tropical islands and areas with large mountains. For example the islands of Fiji and Hawai'i have definite wet and dry sides.

The island of Kauai has one of the wettest places on Earth. Mount Waialale receives 1,184 centimeters of rain per year. The coastline on the opposite side of the island receives only 56 centimeters of precipitation annually .

Transparency of rainfall map of Kauai.



ii. Monthly Precipitation

The measure of precipitation on a monthly basis is probably the most useful for crop production purposes. The amount of water that will be available can be matched for specific crops and their growing period.

iii. Rate of Precipitation

This measure refers to the amount of rainfall in a given period of a storm, usually per hour or day. It is a measure of the intensity of the rain. This is important when there is very little rain in a storm and it does not infiltrate the soil or very much rain which is lost as surface runoff.

iv. Humidity

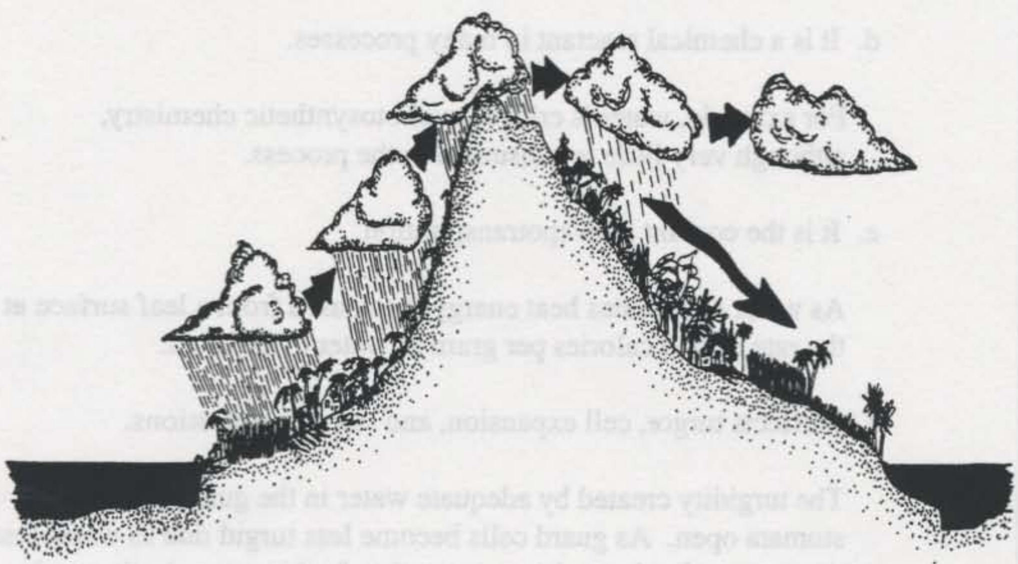
HUMIDITY is water vaporized in the air.

RELATIVE HUMIDITY is the ratio of the weight of water vapor in a given quantity of air to the total weight of water vapor that quantity of air is capable of holding at a given temperature. It is expressed as a percentage.

2. **What factors affect precipitation at different locations?**

a. As temperature increases, the ability of air to hold humidity also increases. Locations close to open bodies of water tend to have higher relative humidity. For Pacific islands, proximity to hills or mountains may have the greatest affect on precipitation.

b. Mountains create a barrier to wind and clouds causing them to rise to higher elevations, growing cooler as they climb. The colder temperature causes moisture to condense and fall on the windward side of the mountains. After the wind passes the highest elevation and moves down the other side it is dry and warm on the leeward side.



Transparency of wind and precipitation patterns near mountains.

c. The effects of other weather patterns such as trade winds may result in uneven distribution of rainfall throughout the year. For example in India and southeast Asia, MONSOON conditions create a very dry climate during most of the year followed by extremely heavy precipitation in the rainy season. Annual rainfall data may suggest that cropping is possible throughout the year, while monthly data makes it obvious that it is not.

3. **How does water affect plants?**

a. It is a necessary part of all cells and tissues.

The amount of water varies between different types of plants and different parts of the same plant. For example, plant seeds are usually much drier than fruits.

Water moves from the soil to the roots, up the stem, and is lost from leaves by transpiration. Roots absorb the majority of water used by a plant. It is the root hairs which are most active. In many plants the area occupied by the roots is roughly equivalent to the area of the plant's above ground parts.

Review translocation in *Plant Science for Pacific islands*

b. It is a solvent for nutrients in the soil and many compounds in the plant cell.

c. It is the medium for the transport of nutrients and products of photosynthesis in the plant.

As roots grow, intercept, and absorb water they are also absorbing (by osmosis and diffusion) the dissolved nutrients carried by the water. Similarly water transports carbohydrates in the phloem to storage locations in the plant.

d. It is a chemical reactant in many processes.

For example, water is critical to photosynthetic chemistry, although very little is consumed in the process.

e. It is the coolant in evapotranspiration.

As water evaporates heat energy is released from a leaf surface at the rate of 540 calories per gram of water evaporated.

f. It affects turgor, cell expansion, and stomate operations.

The turgidity created by adequate water in the guard cells holds stomata open. As guard cells become less turgid due to water loss the stomata begin to close, preventing further transpiration and plant tissue desiccation.

g. Water stress can shut down processes and cause growth disorders. WATER STRESS occurs in plants when water loss exceeds water uptake, causing a reduction in leaf water content. Water stress slows photosynthesis and growth. It can delay flowering, fruiting, cause poor fruit set, and cause such disorders as blossom end rot.

4. **How does the soil affect water availability?**

The amount of precipitation and humidity are not the only factors determining water availability. Soil media is also a critical factor.

a. INFILTRATION RATE is the maximum speed that water can enter the soil under specific conditions. Infiltration rate is affected by the precipitation rate combined with the soil structure and texture, and any surface covering material which slows runoff and protects the surface against compaction.

b. WATER POTENTIAL is the tendency of water molecules to diffuse, evaporate or be absorbed from one area to another. It is usually measured in pressure. Pure water has a water potential of zero and becomes negative as solutes are added, because they inhibit movement.

Water moves from regions of least negative to more negative potential. Within a plant the highest water potential is in the roots and lowest at the stomata.

c. Soil particles in direct contact with water hold it tightly. As distance from a soil particle increases the attraction weakens. When a soil is saturated the water potential is close to zero. As water is removed by evaporation or plant roots the water potential decreases and the remaining water is held more tightly.

5. **What factors affect transpiration?**

Many environmental and plant factors affect transpiration:

a. Insolation. Increased solar radiation causes stomata to open larger.

b. Temperature. Irradiance heats the leaf surface that is cooled by evapotranspiration.

c. Soil water availability for root absorption.

d. Relative humidity. High humidity surrounding a leaf decreases potential evaporation

e. Air movement (discussed more fully in D below). As wind moves air away from stomata, water potential decreases and transpiration increases.

f. Plant adaptations

5. **How have plants adapted to different precipitation conditions?**

a. Limited water conditions

i. Number of stomata. A wide variation between species is found depending on the environment, from 2,000 to 100,000 per square cm.

ii. Protected stomata. Some plants such as pineapple have sunken stomata to reduce the affect of drying wind. Other plants have dense hairs around the stomata.

iii CAM plants, which only open stomata at night.

iv. Leaf orientation. Reduced irradiance and heat.

v. Waxy cuticle. Reduces moisture loss and desiccation.

vi. Extensive and exploratory roots.

b. High precipitation conditions.

i. Leaf shape. Split leaves for increased air movement. Drip tips to dispose of water on leaf surface.

ii. Waxy cuticle to prevent leaching of leaf nutrients.

iii. Surface and air breathing roots. Survival in waterlogged soil.

6. **What are the effects of high precipitation on crop production?**

a. Soil erosion is the movement of soil particles caused by water and/ or air. High precipitation can move soil downhill, which often reduces soil quality at the eroded site. The soil may be carried to a location where it is not useful and damages other resources.

b. A large amount of soil nutrients are leached beyond the reach of plant roots under high rainfall conditions. Nutrients are also leached directly from plant leaves.

c. Waterlogged soils. Soils that remain constantly wet have very limited use for crop production. Under these conditions most plant roots and stems will rot. Decomposition of organic matter must take place in anaerobic conditions.

d. Fungus and disease problems. Many of these problems of leaves, roots and stems prevent specific crops from being produced under high rainfall conditions.

e. Pollination and fruit development. Flying pollinators are inhibited or prevented during high rainfall. Flower and fruit parts may be damaged.

7. **What crop production practices can optimize growth under different precipitation conditions?**

a. Greenhouse coverings. This will prevent excessive rain from reaching the crop. Additional shade can be added to reduce transpiration. Irrigation is required.

b. IRRIGATION is the application of water to a crop or area of soil by a means other than natural rainfall. Some irrigation methods are described below.

i. Overhead irrigation is the application of water to a crop by use of a sprinkler or gun-type irrigator that lies above the soil surface.

ii. Surface irrigation is the direct application of water to the soil surface. For example, crop and furrow flooding or using a hose to irrigate are types of surface irrigation.

iii. Trickle irrigation involves the regular application of relatively small amounts of water directly to the root system of a crop.

c. Mulch and organic matter. MULCH is any material that is spread over the soil surface to protect the soil (from evaporation, and erosion) and control weed growth. Mulches can be man-made (plastic or cardboard) or organic (leaves or sawdust). Organic materials added to the soil improve infiltration and water holding capacity.

d. Plant seasonally. Study of monthly precipitation patterns allows planting of crops to match water requirements. Knowledge of microclimates can also be used in this manner.

e. Split applications of fertilizer. Apply small amounts more often and at critical times to avoid leaching problems.

f. Use fungicides or fungus resistant varieties. Use production practices which prevent spread of disease problems.

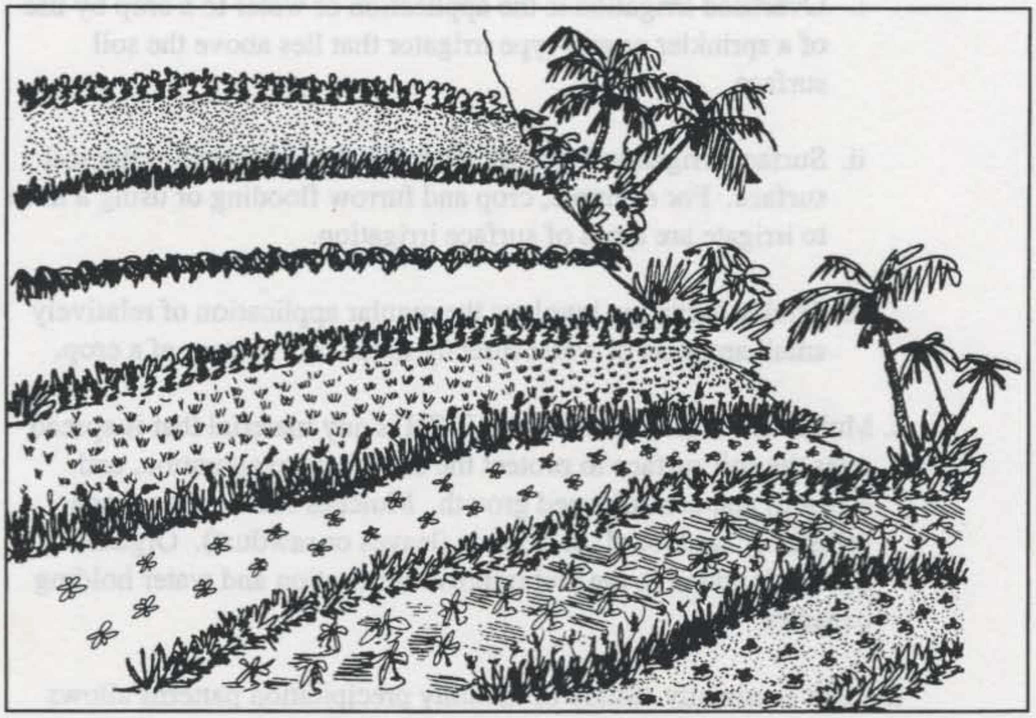
g. Harden off transplants. HARDENING OFF is the treatment of tender plants to help them to survive in a harsher environment. For example: holding back water/nutrients, increasing sun exposure, or allowing temporary wilt.

h. SOIL CONSERVATION is the wise use of land resources through a combination of appropriate practices. Some of these practices are described below.

i. CONTOUR PLANTING is the practice of cultivating and planting land along lines of equal elevation to reduce soil and nutrient erosion.

ii. Contour hedgerows are lines of plants, trees, or shrubs grown along contour lines to help prevent erosion by slowing the downhill flow of water and holding the soil in place.

iii Grassed waterways are planted and maintained to slow the downhill movement of water and reduce gully erosion.



D. Air Movement

1. **How is air movement measured?**

a. Quantity

i. Wind is measured by speed in either meters per second, miles per hour (mph), or knots. A KNOT is a nautical speed measurement equal to 1.15 mph.

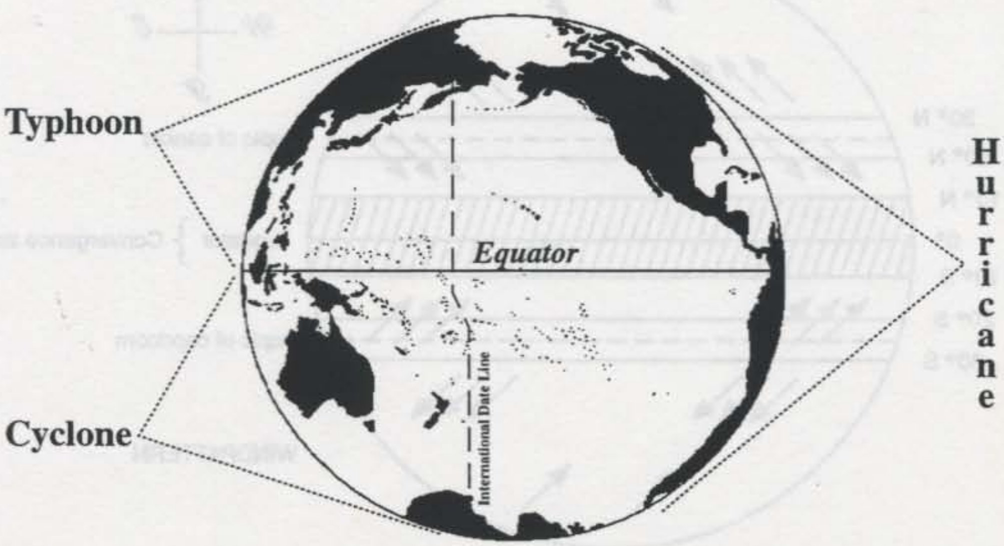
ii. TRADE WINDS are a seasonal pattern of air movement toward the equator that is found in the tropics. Trade winds are usually 10 to 20 knots but may increase to around 30.

iii Extremely high winds often build up in convergence zones and move in relatively predictable patterns. CONVERGENCE ZONES are areas between 10 degrees north and 10 degrees south of the equator which develop accumulated clouds and gusting winds created by changes between the air and water temperatures.

iv. Winds can build in speed upwards of 200 mph and create major destruction to crops, forests and structures. They are classified as:

Tropical depression with winds above 30 mph.
Tropical storm with winds above 40 mph.
Hurricane, cyclone or typhoon with winds above 75 mph.

v. A hurricane is anywhere east of the international dateline (180 degrees longitude), a cyclone is west of the dateline and south of the equator, and a typhoon is west of the dateline and north of the equator.



b. Quality. Air temperature and humidity have been discussed earlier. Other measures of quality include:

i. CO_2 content. The carbon dioxide in the air is a critical element for photosynthesis, which can be deficient in crop canopies. Studies in enclosed structures have shown increased plant growth in CO_2 enriched conditions. The global increase in CO_2 is a major concern in global climate change discussed below.

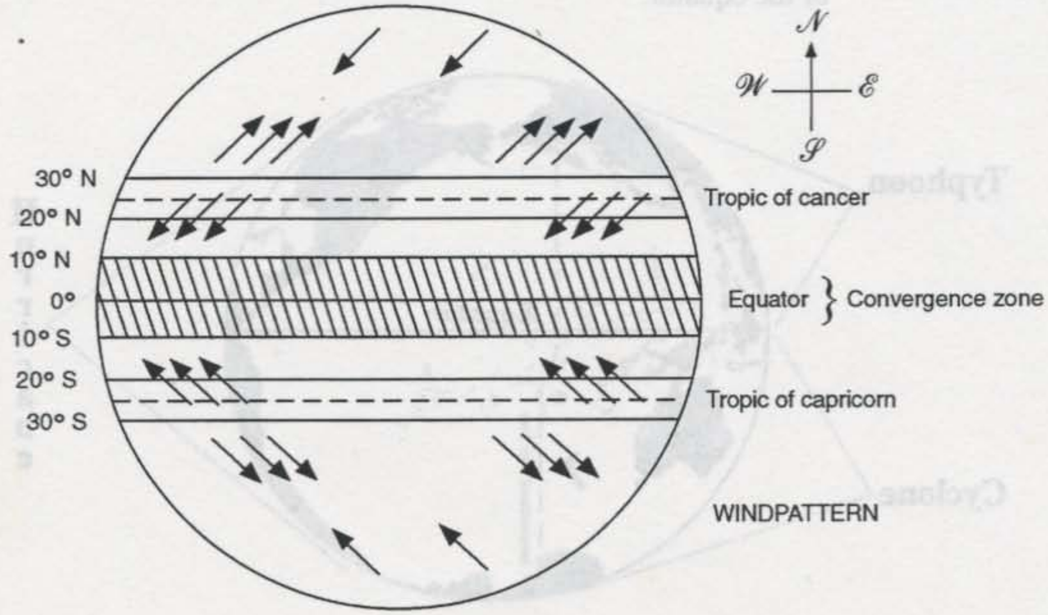
ii. Salt content. Plantings on or near the coast are exposed to salty mists and occasionally salt spray. These conditions prevent many species from being able to survive due to desiccation.

iii Pollutants. Air can be contaminated with materials in high enough concentrations to damage or kill plants. Sulfur dioxide, fluoride, and ozone are the most damaging of air pollutants. The common sources are power plants, industry, and transportation respectively. Dust can also cover plants, blocking sunlight and clogging stomata. Leaves are the plant part most likely to show symptoms of air pollution damage.

2. **What factors affect air movement?**

a. Wind patterns

i. Solar radiation strikes some areas of the earth's surface (tropics) more directly than others. This produces warmer air at the equator which moves toward the poles. The cooler air at the poles drops down in latitude.



ii. The direction of wind flow at the Earth's surface is affected primarily by the rotation of the planet from west to east.

iii A secondary factor is the seasonal changes caused the Earth's rotation around the sun.

iv. Other factors which create local air patterns include:
- convergence zones in particular ocean areas.
- heating/ cooling differences between bodies of land and water.
- differences in elevation and aspect.

3. How have plants adapted to different air conditions?

a. Wind quantity

i. Plants subjected to strong winds may have leaves made of many leaflets (coconut) or leaves that split easily (banana).

ii. Waxy cuticle to prevent excessive moisture loss from evapotranspiration caused by wind.

b. Wind quality

i. Some plants are more tolerant to salt or pollutants in the air than others. Over time, selection and plant adaptations may increase these characteristics within some species or cultivars.

4. What are the effects of air movement on crop production?

a. Pollination. Many plants depend on air movement for cross pollination or self pollination.

b. Wind damage. Some plants can be desiccated with only mild, constant winds. Others such as banana can be badly damaged by tropical depressions or storms. Even very resilient crops such as coconut palms can be broken during a hurricane or cyclone.

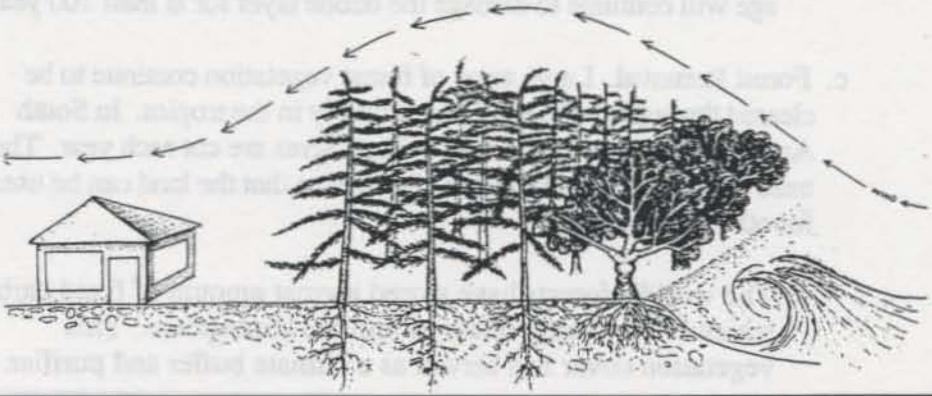
c. Erosion occurs when wind carries soil particles to new locations.

5. How can plants be used to optimize cropping in windy conditions?

a. WINDBREAKS are plantings of trees and tall perennials used to deflect air movement around crops and structures to be protected.

i. Using salt and pollution tolerant species can protect crops from negative affects of these wind quality factors.

ii. The roots of windbreak plants can control wind and coastline erosion.



E. Global Climate Change

The potential change in global climate is a result of conditions affecting all four elements; light, temperature, water, and air movement.

1. It is believed that global temperatures have increased by one degree Fahrenheit in the past hundred years. Predictions are for a further increase of four to five degrees within the next 50 years. Predictions are based upon computer models and some question their accuracy.

2. Warming is not expected to be equal globally and predictions for specific locations are the most difficult. The greatest warming is predicted at the poles--up to 18 degrees--particularly in the winter.

3. Some specific predictions are that Canada and Russia would become warmer with longer growing seasons. England and surrounding countries would have increased precipitation. Northern Africa and the Southwestern U.S. would become drier. The Midwestern U.S. corn belt would have longer growing seasons but a drier climate.

4. Three factors are considered major contributors to global warming:

Discuss how changes in the global climate may affect Pacific islands.

Consider effects such as a rise in sea level, increased temperatures, weed growth, storms, etc.

   a. Increased CO_2 in the atmosphere. Carbon dioxide build up magnifies the greenhouse effect. The GREENHOUSE EFFECT is the absorption and retention of solar radiation by the Earth's atmosphere. The atmosphere acts like a greenhouse covering around the Earth, allowing solar radiation to enter but trapping heat which can not pass back out.

   - CO_2 is measured in parts per million (ppm) within the atmosphere. Amounts have been measured showing change from 315 ppm in 1958 to 340 ppm in 1989.

   b. Ozone depletion. Ozone forms a protective layer in the atmosphere which blocks out the far ends of the solar radiation spectrum. Industrial processes and chemicals have been depleting the ozone layer. Most damaging has been Chlorofluorocarbons (CFC) found in refrigerator and air conditioning coolants and a by-product of the manufacture of styrofoam.

   - Although the use of CFCs has been sharply restricted in most countries, CFCs emitted since the beginning of the industrial age will continue to damage the ozone layer for at least 100 years.

   c. Forest Removal. Large areas of forest vegetation continue to be cleared throughout the world-particularly in the tropics. In South America it is estimated that 27 million acres are cut each year. These trees are commonly cleared and burned so that the land can be used for other purposes.

   - The world's forests have stored a great amount of fixed carbon which is now being released into the atmosphere. This vegetation cover had served as a climate buffer and purifier.

Introduction to World Food Crops

3

Introduction to World Food Crops 3

Performance Objectives

Upon completion of this chapter each student should be able to:

A. Define the 32 terms related to world food crops.

B. Explain three reasons plant classification is important.

C. Name and describe five artificial methods of crop classification.

D. Describe six ways of classifying plants by ecological or climatic requirements.

E. List at least six "common use" categories of crop plants and give two local examples from each category.

F. List the seven taxa of phylogenetic classification in proper descending order.

G. List at least six important families of crop plants and give examples of local crops in each family.

H. Match the scientific names of at least six important local crops with their cultivar and/or common name.

I. Describe the process of identifying an unknown plant.

J. Describe at least five important periods in the timeline of agriculture.

K. List the fifteen crops that provide the majority of the world's food crops and place them into five categories.

L. Explain how physical resources, technology, and information affect crop production in different regions of the world.

M. List the six steps in the scientifc method.

N. Name and describe at least two current trends in crop improvement, production methods, and agricultural engineering

Terms

ACRE (ac)- A unit for measuring land equal to 43,560 square ft., or 1/640 of a square mile.

ANNUAL PLANTS- Plants that live for one year, or one growing season.

ARABLE LAND- Land suitable for farming which can be utilized for growing crops.

ARTIFICIAL CLASSIFICATION- Classification system developed for convenience and based on use, cultural requirements, or other superficial characteristics rather than relationships between plants.

BIENNIAL PLANTS- Plants that live for two years.

BINOMIAL NOMENCLATURE- The scientific name of a plant, consisting of genus and species names.

BIOTECHNOLOGY- The application of molecular biology and genetic engineering to agriculture, industry and medicine.

CULTIVAR- A cultivated variety.

DOMESTICATION- The process of bringing a wild species into human management.

FEED CROPS- Crops that are produced for consumption by livestock.

FERTILIZER EFFICIENCY- The measure of the conversion of fertilizer into harvested crops.

FIBER CROPS- Crops produced to create raw materials for textiles, cordage, and building products.

FOOD CROPS- Crops produced for human consumption.

HECTARE (ha)- A land area of 10,000 meters^2, equal to about 2.5 acres.

HERBARIUM- A collection of dried plant specimens.

HYDROPONICS- Growing plants in water and/or a soil-less media while providing all the esssential nutrients.

INDUSTRIAL CROPS- Crops that are grown for a wide variety of products, extracts, and derivatives.

INTEGRATED PEST MANAGEMENT- A combination of biological, cultural, and mechanical pest control practices with chemicals used as a last alternative.

IRRIGATION- The application of water to land for the production of crops.

MECHANICAL HARVESTERS - Equipment that has greatly reduced the labor needed to harvest crops, (eg., cotton gin, combine, and tomato pickers).

OIL CROPS- Plants grown to produce lipids for human or animal consumption, or industrial purposes.

ORNAMENTAL CROPS- Plants grown for use in landscaping and decoration.

PERENNIAL PLANTS- Plants which live from several to many years.

PHYLOGENETIC CLASSIFICATION- A system that classifies plants according to their apparent evolutionary relationship.

PLANT CLASSIFICATION- A continuously evolving system of grouping plants according to their relationships to each other.

PLANT IDENTIFICATION- The process for determining the identity of an unknown plant.

PLANT MORPHOLOGY- The study of a plant's external shape and form.

POST HARVEST TECHNOLOGIES- New methods to handle, preserve, transport, and store crops after removal from the field.

SELECTION- The process of controlled reproduction of a domesticated species.

TAXONOMY- The study of plant classification.

TISSUE CULTURE- Growing masses of unorganized cells for rapid asexual multiplication of plants.

VARIETY- A named group of plants within a species which can be identified by a set group of characteristics.

I. Classification of Crop Plants

A. Introduction

TAXONOMY is the study of plant classification. PLANT CLASSIFICATION is a continuously evolving system of grouping plants according to their relationships to each other. Knowledge of plant taxonomy and classification is useful in determining the identity of an unknown plant.

1. **What is the importance of classifying plants?**

    a. Plant classification creates a man-made system to describe the natural botanical world.

    b. Classifications enable those in the scientific community to communicate information effectively.

    c. It makes plant identification easier.

SA

Have students "classify" themselves based on categories they suggest and form groups based on those categories. The instructor should suggest some categories to get things started.

B. Classification Systems

1. **What are the two basic classification systems?**

    a. ARTIFICIAL CLASSIFICATION is a system developed for convenience and based on; use, cultural requirements, or other superficial characteristics, rather than relationships between plants.

    b. PHYLOGENETIC CLASSIFICATION is a system which classifies plants according to their apparent evolutionary relationship. This system is limited by scientist's lack of knowledge of earlier plant forms. Many plant relationships are now being based on cytogenetics, paleobotany, biochemistry, and other relatively new sciences.

2. **What are five methods of artificial classification?**

    a. The concept of useful vs harmful is one of the earliest artificial classification systems, and is still used to some degree.

        i. Useful plants include those that can be used for food, fiber, and medicine.

        ii. Harmful plants were those that are poisonous or are in competition with crops.

b. Classifying plants according to their life span or growth pattern is another artificial system of classification that is used.

i. ANNUAL PLANTS live for one year, or one growing season. Most major crop plants, including cereal grains and vegetables, are examples of plants that could be classified as annual plants.

ii. BIENNIAL PLANTS live for two years. These plants usually have vegetative growth during the first year and store nutrients during a dormant season, then flower, set seed, and die after the second season.

iii. PERENNIAL PLANTS live anywhere from several to many years. Papaya, banana, pineapple, sugarcane, and most fruit or nut bearing trees are perennial crops.

c. Some classification systems focus on a plant's ecological or climatic requirements. Examples include:

i. Moisture. Different plants have different water requirements. Classifications include xerophyte, mesophyte, and hydrophyte.

ii. Temperature. Warm season or cool season plants are labeled according to what temperature they grow in. Cool season crops can sometimes be grown at high altitude in the tropics.

iii. Climate. Plants are sometimes classified by their ability to grow in tropical, subtropical, or temperate regions. This is very imprecise, however, as many crops can grow in two or all three climates.

iv. Stress tolerance. Tolerance (low or high) to acid soils, basic soils, aluminum, manganese, salt, heat, and moisture are often used to classify a plant.

v. Photoperiod. Some plants only reproduce or develop reproductive structures with a certain amount of sunlight. Short-day, long-day, and day-neutral are some quantifiers used to describe these plants.

vi. Light intensity. Some plants are able to tolerate only a certain amount of solar radiation, so some plants are labeled either sun plants or shade plants.

d. The morphology of a plant is often used for classification. PLANT MORPHOLOGY is the study of a plant's external shape and form. Some common morphological classifications include:

i. Leaf retention. Trees that lose their leaves annually are called deciduous, while evergreens keep their leaves year round.

ii. Broad leaf trees vs. needle leaf trees.

iii. Broadleaf vs. grass. This classification is often used to classify weeds.

iv. Woody vs. herbaceous. Woody plants include trees, shrubs, and lianas. Examples of herbaceous plants are herbs and vines.

e. Plants are also classified by their common use. This method is imprecise because a single crop can often fit into several groups. For example, corn can be grown for food, animal feed, oil, production of alcohol, or any combination of those things. Some various classifications by use:

Discuss other local crops that fit into the common use system.

i. FOOD CROPS are produced for human consumption. Corn, potato, wheat, taro, and rice are examples of food crops.

ii. FEED CROPS are produced for livestock consumption. Corn, soybeans and hay are examples of feed crops.

iii. FIBER CROPS are produced to create raw materials for textiles, cordage, and building materials. Some examples include cotton, manila hemp, and kapok.

iv. OIL CROPS produce lipids for human or animal consumption, or industrial purposes. Corn, soybeans, and coconuts are all examples of crops that can be harvested for their oil content.

v. ORNAMENTAL CROPS are used for landscaping and decoration. orchids, roses, and bonsai trees are examples of ornamentals.

vi. INDUSTRIAL CROPS used in a wide variety of products, extracts, and derivatives. Cigarettes, rubber, and rice wine are all produced from industrial crops.

3. **How does the phylogenetic system classify crops?**

a. The phylogenetic system is based on the evolutionary relationships that exist between plants. Classifying plants in this manner provides scientists with a powerful tool for characterizing and organizing the diversity of plant organisms.

b. The system is based mainly on the reproductive (flower) parts, which are altered less by the environment than vegetative characteristics.

c. The units of classification in the phylogenetic system are known as TAXA. All of the taxa except species are based on evolutionary relationships. The major taxa are:

Kingdom
  Division
    Class
      Order
        Family
          Genus
            Species

d. In addition to the scientific taxa, plant scientists use the terms variety and cultivar. A VARIETY (var.) is a named group of plants within a species which can be identified by a set group of characteristics. A CULTIVAR (cv.) is a cultivated variety.

i. There can be many cultivars within a species, and even within a variety. Tomatoes and cabbage are just two examples of this diversity.

ii. New cultivars are continually being developed. Some of the reasons for developing new cultivars include increasing the disease resistance, vigor, quality, and yield of a plant as well as producing a plant that is better adapted to its climate.

e. There are two major benchmarks in the development of the phylogenetic system.

i. Linnaeus, the "father of taxonomy," wrote <u>Species Plantarum</u> in 1753. His ground breaking work classified over 1,300 plants and his method of classifying plants is the foundation of the phylogenetic system today.

SA

Create lists of local cultivars of important traditional crops.

ii. Darwin published the Origin of Species in 1859. His work established the concept of evolutionary relationships. According to his theory, living things are related by their proximity on the family tree of evolution.

iii. Today, reclassification continues with the new tools of taxonomy: cytology, genetics, protein electrophoresis, and chromatography of pigments.

SA

Interested students can research how one or more of these techniques is used in taxonomy.

f. BINOMIAL NOMENCLATURE The scientific name of a plant consists of the genus and species names.

i. The name of the genus comes first and its first letter is always capitalized. The species name follows, and is never capitalized.

ii. Scientific names should always be written in italics (eg., *Cocos nucifera*), or underlined (eg., Zea mays or Colocasia esculenta).

iii. Cultivar names follow the scientific name, and are usually enclosed in single quotes: Brassica oleracea cv.'Golden Acres'.

g. Major families of crop plants

Araceae- taro (Colocasia, Cyrtosperma, Xanthosoma)

Bromeliaceae- pineapple

Chenopodiaceae- beet, sugar beet, spinach

Convolvulaceae- sweet potato, kangkong

Cruciferae- cabbage, Chinese cabbage, broccoli

Cucurbitaceae- pumpkin, melon, cucumber, bitter melon

Euphorbiaceae- cassava

Graminae (Poaceae)- wheat, corn, sugarcane, rice, oats

Leguminosae (Fabaceae)- beans, soybean, peanut, alfalfa

Musaceae- banana, Manila hemp

Palmae- coconut, betel (areca) nut, date, oil palm

Rutaceae- orange, lemon, lime, tangerine, grapefruit, pomelo

Rosaceae- apple, rose, peach, apricot, pear, plum

Solanaceae- tomato, potato, eggplant, pepper

Umbrelliferae- carrot, celery, parsnip

Review objectives G. and H. for this chapter.

Study the taxonomic families of local crops.

Create a list of local cultivars of important traditional crops

Develop the full classification from Kingdom to Species for selected crops.

h. Examples of classification of specific crop plants:

Taro

Kingdom	Plantae	
Division	Spermatophyta	(seed bearing)
Class	Angiospermae	(seeds in fruit)
Sub-class	Monocotyledonae	(single seed leaf)
Order	Arales	
Family	Araceae	
Genus	Colocasia	
Species	Esculenta	

Head Cabbage

Subclass	Dicotyledonae	(two seed leaves)
Order	Papaverales	
Family	Cruciferae	
Genus	Brassica	
Species	Oleracea	
Variety	Capitata	
Cultivar	'Golden Acres'	

Pfitzer Juniper

Class	Gymnospermae	(seed not in fruits)
Order	Coniferales	
Family	Cupressaseae	
Subfamily	Cupressoideae	(also called Cupressineae)
Tribe	Juniperae	(often omitted)
Genus	Juniperus	
Species	Chinensis	
Cultivar	'Aurea'	

5. **How are classification systems used for plant identification?**

Steps in plant identification

- Develop a knowledge of the vocabulary of plant morphology.
- Obtain keys, plant manuals, floras and other references which describe plants of a given region, or of a particular family or genus.
- Visit herbaria. A HERBARIUM is a collection of dried plant specimens.
- Compare with herbarium specimens, or with living specimens, usually contained in botanical gardens.
- Seek a known authority (e.g. Hortus Third or Flora of Hawaii).
- Ask a taxonomist or other knowledgeable person for assistance. Obtain permission to send plant specimens to a taxonomist.

OPT

Visit a herbarium to study specimens and identify plants

II. Development of Crop Production

A. Timeline of agriculture

5,000,000,000 years ago	Earth formed
300,000,000 years ago	Earliest dinosaurs
4,000,000 years ago	Earliest humans, food gatherers and hunters.
12,000 years ago	Last glaciers begin retreat.
10,000 years ago	Neolithic revolution: people began to domesticate plants and settle into villages (began in Middle East, Iraq/Egypt).
8,000 years ago	People in Southeast Asia and Latin America began farming.
6,000 years ago	People in Central Africa and China began farming.
500 years ago	Age of Exploration: Ships travelled all over the world in search of spices, gold and converts. Brought back plants and crops from other parts.
250 years ago	Industrial Revolution: Farmers in England began using new breeding techniques. Increased food production released labor from the farms to work in factories. New sources of energy and technological advances lead to rapid changes and higher outputs in agriculture.
40 years ago	Green Revolution: Increased use of science to solve agricultural problems lead to adoption of new varieties, chemical pesticides and fertilizers, and increased mechanization throughout the world; with many successes and some failures. (Rockefeller foundation set up the international research centers.)
1970s to present	Environmental Revolution: Increased concern about effects of the Industrial and Green Revolution on Earth's environment. Move toward organic lifestyles, appropriate technologies, and sustainable development systems.

B. Crop production throughout the world

1. How were crops developed?

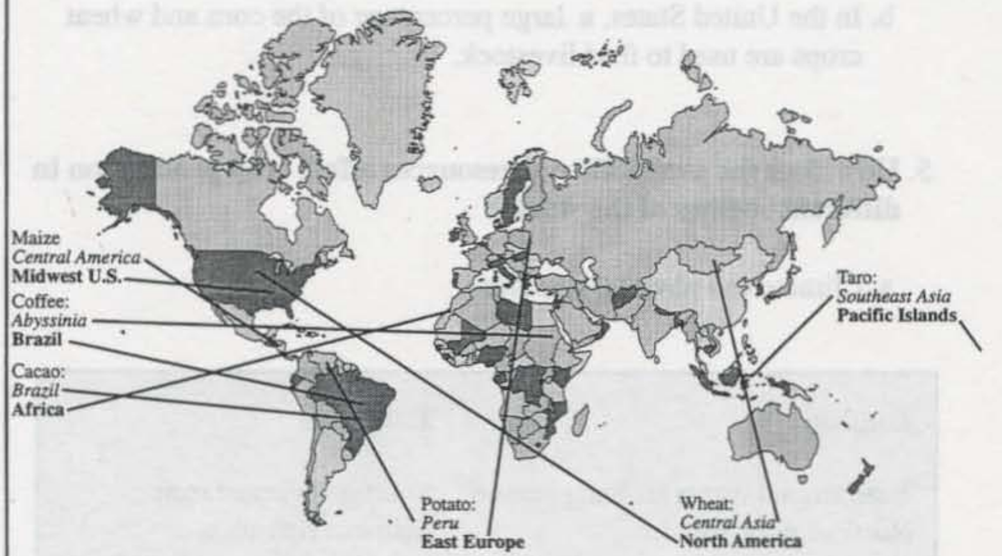
a. Practically all of our food crops were developed first in prehistoric times, long before the birth of Christ. This development was the result of two separate processes:

i. DOMESTICATION is the process of bringing a wild species into human management.

ii. SELECTION refers to the controlled reproduction of a domesticated species.

2. How were crops spread from their original locations?

a. Crop plants have been carried by man as he migrated and colonized the world. For example, evidence shows that taro was spread throughout the Pacific and as far east as the Mediterranean in prehistoric times. Many crops are grown today in places far from their origin.



Centers of origin are *italicized*. Centers of modern production are **boldfaced**.

SA

Transparency of map showing centers of origin

3. What are the major food crops of the world?

a. There are fifteen types of field crops that provide the majority of the world's food.

b. These crops can be placed into five groups.

Cereals	"Root" Crops	Legumes	Sugar Crops	Tropical Crops
Rice	Potato	Beans	Sugarcane	Banana
Wheat	Sweet Potato	Soybean	Sugar Beet	Coconut
Corn	Cassava	Peanut		
Sohrgum				
Barley				

4. **Which crops are produced in the greatest amounts worldwide?**

   a. Four crops account for more of the world's foods than all the other crops combined together.

Crop	Leading Producer
Rice	Asia
Wheat	Russia
Corn	United States
Potato	Europe

   b. In the United States, a large percentage of the corn and wheat crops are used to feed livestock.

5. **How does the availability of resources affect crop production in different regions of the world?**

   a. Climate and physical resources.

Tropical	Temperate
Year around warm growing season	Short growing season
Nutrient poor soils	Nutrient rich soils
More pest and disease problems	Pest/disease control - Winter

   b. Technology and Information

      i. Developed countries (mostly located in the temperate climates) generally use more hybrid seeds, fertilizers, chemicals, and machinery.

      ii. These countries usually have greater access to information on how to use resources for modern, industrial agriculture.

Countries are ranked from one (the most amount) to seven (the least amount) on various factors that affect food crop production.

	North America	Europe	Africa	Russia	China	Asia	South America
% of workers in agriculture	<5% 5	10% 4	60% 1	20% 3	60% 1	60% 1	40% 2
Acres[1] of arable[2] land per worker	1	3	5	2	7	6	4
% of arable land in production	58% 4	81% 1	25% 5	65% 3	?	72% 2	19% 6
Mechanization #tractors/acre	2	1	6	3	4	6	5
Land under Irrigation[3]	3	3	4	3	1	2	3
Fertilizer use/ hectare[4] arable land	3	1	6	4	?	2	5
Harvest in tons/ hectare arable land	3	1	5	4	?	2	4
Fertilizer Efficiency[5]	2	5	1	4	3	3	?

Footnotes:

1.ACRE (ac) is a unit for measuring land equal to 43,560 square ft., or 1/640 of a square mile (about the size of a football field).

3.HECTARE (ha) is a land area equal to about 2.5 acres.

2. ARABLE LAND is land suitable for farming which can be utilized for growing crops.

4. IRRIGATION is the application of water to land for the production of crops.

5. FERTILIZER EFFICIENCY is the measure of the conversion of fertilizer into harvested crops.

In the examples from this table, dividing the kilograms of fertilizer per hectare into the tons of harvest per hectare gives the fertilizer efficiency. However, other energy inputs are involved such as mechanization and irrigation.

OPT

Organize a panel to discuss these ideas.

Students can role play as representatives from different world regions.

c. Generalizations can be drawn from the table on the previous page:

i. North America has the smallest agricultural work force with the largest amount of arable land. It is in the median range for use of land, machinery, irrigation, and fertilizer, and in the middle with regard to crop production per hectare.

ii. Europe has the second smallest agricultural work force, is in the middle regarding amount of arable land, but uses the greatest amount of its land, machinery, and fertilizer, resulting in highest crop production per acre.

iii. Africa and Asia have the largest agricultural work force and the smallest amounts of arable land. Africa uses only 25 percent of its arable land and Asia is second worldwide using 72 percent . Both countries use little mechanization, but Asia uses large amounts of irrigation and fertilizer while Africa uses the least out of the seven crop-producing regions surveyed. The result is that Asia has the second highest (tons/hectare) harvest but Africa is lowest worldwide.

d. The combined climate, physical resources, technology, and information systems in the U.S. result in the ability of the Midwestern farmer to produce as much corn on one hectare as can be produced on 10 hectares in Africa or South America

e. Improved varieties and cropping practices can make a huge difference in the harvest per acre as shown by this comparison of average and record yields:

Effect of inputs on crop yield

Crop	Average yield*	Record yield*
Corn	72	307
Wheat	28	216
Soybeans	45	110
Potatoes	420	1400

*Measured in bushels per acre

6. **How has applied scientific research improved crop production?**

a. Crop production has been a form of applied science from the first efforts at plant domestication. Early practices by trial and error developed into true agricultural research as the scientific method was refined in the sixteenth and seventeenth century.

b. Steps in the scientific method

i. Identify the problem

ii. Study available information

iii. Develop a hypothesis

iv. Design and conduct experiment(s)

v. Observe and record data

vi. Determine a conclusion based upon the data

c. Some early scientists and their agriculturally related discoveries:

i. Robert Hooke (1935-1703) - named & described cells

ii. Carl von Linne (1707-1778) - classification by morphology

iii. Joseph Koelreuter (1733-1806) - hybridization experiments

iv. Gregor Mendel (1822-1884) - inherited characterisitics

d. Beginnings of agriculture sciences:

i. Justis von Liebig (1803-1873) - plant nutrition, ag. chemistry

ii. Louis Pasteur (1822-1895) - role of microorganisms in disease

iii. John Bennet Lawes (1814-1901) improved fertilizer practices

OPT

Develop an example using agricultural research at your home institution.

SA

Scientific discoveries and current trends can all be used for reports and independent study.

e. Recent improvements and current trends

i. Crop Improvement

• BIOTECHNOLOGY- The application of molecular biology and genetic engineering to agriculture, industry and medicine.

• TISSUE CULTURE- Growing masses of unorganized cells for rapid asexual multiplication of plants.

ii. Production Methods

• HYDROPONICS- Growing plants in water and/or a soiless media while providing all the esssential nutrients.

• INTEGRATED PEST MANAGEMENT- A combination of biological, cultural, and mechanical pest control practices with chemicals used as a last alternative.

iii. Agricultural Engineering

• MECHANICAL HARVESTERS - Equipment that has greatly reduced labor in crop harvests, (eg., cotton gin, combine, and tomato pickers).

• POST HARVEST TECHNOLOGIES- New methods to handle, preserve, transport, and store crops after removal from the field.

OPT

Use guest speakers that are specialists in these subjects for classroom presentations / field trips.

Production of Major World Food Crops

4

Production of Major World Food Crops 4

Performance Objectives

Upon completion of this chapter each student should be able to:

A. Define the 18 terms related to the production of major world food crops.

B. Identify the scientific names of the major world food crops.

C. Explain seven reasons why cereals are important to world food crop production.

D. Describe the locations and conditions of world rice production.

E. Describe at least two characteristics of long grain, medium grain, and short grain rice.

F. Explain the different rice production methods in at least three specific parts of the world.

G. Describe the locations and conditions of world corn production.

H. Describe five different types of corn.

I. Explain the different corn production methods used by primitive and modern cultures.

J. Describe the locations and conditions of world wheat production.

K. Explain three differences between hard wheat and soft wheat.

L. Describe at least two practices in each of the four regional wheat production methods described.

M. Explain two reasons why legumes may be the most important world food crops.

N. Describe the locations and conditions of world soybean production.

O. Describe the cultural practices of mechanized soybean production.

P. Explain the uses of soybeans and other legumes by developed and less developed countries.

Q. Describe the locations and conditions of world peanut production.

R. Describe how peanuts are grown and harvested.

Chapter 4 objectives, continued

S. Describe six growth characteristics of sugarcane.

T. Explain the steps in the cultivation and processing of sugarcane

U. Describe the steps in selecting the best coconut seed for propagation.

V. Describe the seven steps in managing a coconut nursery.

W. Explain two methods of spacing seedling trees in a coconut plantation

Terms

BAGASSE- The fibrous residue of sugar cane stems.

CEREALS- Crop plants that are members the Graminae family.

COMBINE- A farm machine that harvests, threshes, and cleans grains and legumes while moving over the field.

DOUBLE CROPPING- The practice of producing two crops on one piece of land during separate growing seasons within the same year.

GRAIN- The fruit of a cereal plant which has an ovary wall that turns hard and fuses with a single seed.

GREEN MANURE- A crop grown for the purpose of improving the soil on a piece of land that will be used for growing other crops.

INTERCROPPING- The practice of growing more than one crop on one piece of land at the same time.

LEGUMES- The fruit and/or seed from plants in the Leguminosae family.

LODGING- The failure of a plant stem to bear the weight of the top of the plant.

NITROGEN FIXATION- The biological conversion of elemental Nitrogen (N_2) into organic combinations usable by living things.

PADDY FIELD- A heavily irrigated or lightly flooded piece of land where crops are grown in standing water.

PEGGING- The growth of the peanut flower pedicel which pushes it below the soil.

RATOON- The regrowth of a plant from its crown or stem.

PREEMERGENCE HERBICIDE- A form of weed killer that controls plant growth before the crop seedlings appear above the soil surface.

RUST DISEASE- A fungal problem of wheat that greatly reduces yield.

SYMBIOSIS- The condition that exists when two species live closely together and both benefit from the association.

THRESHING- The removal of mature grain from a dry cereal plant.

ZERO TILLAGE- A practice that uses specialized equipment to control weeds, plant seed, and fertilize those seeds without major disturbance or cultivation of the soil surface in the entire field.

I. Cereals

A. Introduction

CEREALS are crop plants that are members of the grass (Graminae) family. The primary cereal crops are rice, corn, and wheat. GRAIN is the fruit of a cereal plant which has an ovary wall that turns hard and fuses with a single seed.

1. Why are cereals so important to world crop production?

a. Cereals are annual crops requiring only one growing season.

b. They adapt well to a variety of climates and soil types.

c. They can be cultured in many different ways.

d. The plants make efficient use of land and sun, as a result of upright growth and close spacing distances.

e. Cereals don't have an exceptional amount of pest or disease problems.

f. Cereals are easily handled, harvested, and cleaned.

g. They are easily stored without special preparation, other than drying and preserving.

B. Rice (Oryza sativa)

Rice is the major staple food for 60 percent of the world's population. It has been domesticated and grown in China for more than 5000 years.

1. Where is rice usually grown?

a. Most of the world's rice crop is grown in the warm, wet climate of tropical Asia. One percent of the world production is grown in areas of the United States including; California, Louisiana, and Texas. Dryland rice is grown in Africa, but yields per acre are low.

b. The best land for rice production is level with raised sides to control flooding and irrigation. PADDY FIELDS are heavily irrigated or lightly flooded pieces of land where crops are grown in standing water.

2. What different types of rice are grown?

a. Different types of rice are grown depending on the length of the growing season and consumer preferences.

b. Different rice types are classified by the length of their grain and their maturity period.

Some varieties of rice

Long Grain	•needs longest time to reach maturity, grown in tropics •does not turn sticky when cooked •the preferred type in developed countries
Medium Grain	•shorter growing season than long grain •softer and stickier then long grain •commonly grown in Southeastern U.S. and California
Short Grain	•shortest growing season, good in temperate climate •soft and sticky, preferred in some Asian countries •commonly grown in Japan

3. **How do the methods of rice production vary in different parts of the world?**

a. Thailand:

•Paddy field is flooded to soften the ground.
•Ground is cultivated using water buffalo pulling a forked stick.
•Seedlings are transplanted into the field to give the crop a good start before weeds begin to grow.
•No commercial fertilizers or pesticides are commonly used.
•Paddy is drained and harvested by hand.
•The whole seed stalk is cut and tied up then left in the sun to dry.
•Seeds are threshed from plants by beating them on the ground.

b. Philippine Islands:

•Production methods are very similar to those in Thailand.
•The International Rice Research Institute (IRRI) is located in the Philippines. Subsequently, 70 percent of all rice varieties grown are the high-yielding "green revolution" cultivars.
•These cultivars need closer care and more fertilizer, but the average farmer may not have the knowledge or money needed to properly practice the required techniques.

c. Japan:

•A complete fertilizer is broadcast and plowed in before the paddy is flooded.
•Seedlings are transplanted by hand.
•Plants are top dressed with fertilizer just before forming heads.
•Paddy is drained, then harvesting and threshing is done by small portable machines.

d. United States of America:

•Large flooded paddies are seeded by airplane.
•Herbicides and fertilizer are applied by airplane.
•Large mechanical harvesting and THRESHING equipment is used to harvest the rice.

Transparency of fertilizer and rice yield data

Examples of fertilizer and rice yield data

Country	Fertilizer (kg/ha)	Yield (tons/ha)
Thailand	No fertilizer	1.2
Philippines	5(N) 5(P) 3(K)	1.3
Japan	85(N) 57(P) 62(K)	4.5
U.S.A. (California)	140(N) 50(P) * (K)	5.5

* based upon soil tests for deficiency

4. **How are rice grains processed?**

a. Before processing, the rice is brown in color, high in vitamin B, and its protein content is about eight or nine percent.

b. Processing removes the hulls and polishes the rice until it is white. Very little protein, vitamins, or fiber are left.

C. Corn (<u>Zea</u> <u>mays</u>)

1. **Where is corn grown?**

a. Corn is currently grown throughout the humid, temperate regions of the world. It originated in Central America as a wild plant 80,000 years ago.

i. The cross breeding of hybrids has been relatively easy because it is a monoecious plant with the male (staminate) flowers at the top and the female (pistillate) flowers down amongst the leaves.

ii. Corn has been changed so much by hybridization that today it must be given a lot of care in terms of planting, fertilization, pest control, and harvesting.

2. **What are five different types of corn?**

a. Field corn

i. Flint Corn • has kernels of hard starch.

ii. Dent Corn • has kernels of hard starch capped with soft starch and is the highest yielding type.

iii. Flour Corn • has kernels of soft starch, well suited to grinding by hand.

b. Other types of 'popular' corn

i. Sweet Corn • eaten while still immature and sugars have not changed to starch.

ii. Popcorn • kernels burst open when heated due to moisture trapped inside.

3. **How did primitive cultures cultivate corn?**

a. The indians of Central and North America originally planted corn as the major staple crop using a slash and burn form of agriculture.

b. Planting was done by poking a hole in the soil and inserting a seed.

c. Fertility was managed by adding fish parts to the hole.

d. Other crops, such as beans and squash, were commonly intercropped with corn. INTERCROPPING is the practice of growing more than one crop on one piece of land at the same time.

4. **How do modern cultures cultivate corn?**

a. In mechanized agriculture, fields are often broadcast fertilized and cultivated in the fall. This often creates erosion problems because the soil is left unprotected from powerful Spring rains.

b. ZERO TILLAGE is now a popular method of establishing a corn field. This agricultural practice uses specialized equipment to control weeds, plant seed, and fertilize those seeds without major disturbance or cultivation of the soil surface in the entire field.

Review fertilizer use in *Plant Science for Pacific Islands*

c. Corn is planted at the first sign of warm weather. This creates a longer growing season and the corn's early start shades out competing weeds.

d. Fields are regularly checked for pest and disease problems.

e. The corn is side dressed with fertilizer at the start of flowering.

5. **What products are made by processing corn?**

More than 300 commercial products are made from corn.

a. Corn starch is made by wet milling the harvested grain.

b. Corn starch may be further refined, dried or fermented to make corn sugar, and corn syrup.

c. Corn oil is made by crushing and steaming the grain embryo, then extracting the hull. It is further refined into cooking and salad oils.

d. Gum-like materials are used for industrial materials such as glues and adhesives.

D. Wheat (<u>Triticum</u> <u>aestivum</u>)

1. **Where is wheat grown?**

   a. Wheat is adapted to climates that are cold and dry, where many other crops cannot be grown.

   b. Wheat can be grown anywhere that has moderate moisture and cool weather for early growth, bright sun for maturing the grain, and a dry period for harvest.

   i. These areas are found in the temperate zones of the world.

   ii. The tropics are not well suited for wheat growing due to disease problems and polar regions don't have a long enough growing season.

   c. Leading producers of wheat worldwide are Russia, the U.S., China, Canada, and France.

2. **What are the two basic types of wheat?**

a. Hard Wheat	•grown in areas of limited rainfall; (eg, Russia, U.S. great plains, and China). •higher in protein and better for baking •its primary use is for bread making
b. Soft Wheat	•grown in humid areas, (eg. Europe and U.S. corn belt) •higher in starch, used for pastries •its primary use is for livestock feed

   c. A third type of wheat is Durham Wheat, which is used for making macaroni and spaghetti.

3. **What are some of the regional methods of growing wheat?**

   a. Winter wheat

   i. Varieties that can survive below freezing temperatures.

   ii. Seeds are planted in the Fall and start growing before Winter.

   iii. The wheat remains dormant until Spring at which time it has a quick start.

   iv. The crop matures early in the Summer.

b. Spring wheat

i. The seeds are planted after the ground softens in the Spring.

ii. This type of wheat has a short growing season of 90 -100 days.

c. Dryland practices

i. The wheat is only planted every second year .

ii. This is necessary to allow water reserve build up in the soil.

iii. Limited amounts of fertilizer are used.

d. Humid region practices

i. Wheat is not constantly grown because corn and soybeans bring more money per bushel.

ii. Wheat is grown in rotation with other crops for crop diversification and soil improvement.

iii. Wheat grown in humid regions with adequate fertilizers can get double the yield of dryland wheat production.

iv. Double cropping winter wheat with soybeans is also a common practice. DOUBLE CROPPING is the practice of producing two crops on one piece of land during separate growing seasons within the same year.

4. **What are some common wheat diseases and problems?**

a. RUST DISEASE is a fungal problem of wheat that can greatly reduce the crop yield.

i. Although new resistant hybrids are developed, the fungus soon mutates and the new varieties are often attacked by the new form of the rust fungus.

b. LODGING is a failure of the plant stem to bear the weight of the top of a plant. This often occurs when heavy rains fall on mature wheat crops.

II. Legumes

A. Introduction

LEGUMES are the fruit and/or seeds from plants in the Leguminosae family. Legumes are the second largest group of crop plants grown worldwide for food production. Although cereal crops are produced in larger amounts, legumes may be more important for two reasons.

1. **What is the importance of the legume family?**

a. Legumes live in symbiosis with certain bacteria that grow inside nodules of the plant roots. SYMBIOSIS occurs when two species live closely together and both benefit from the association.

i. Bradyrhizobium spp. is the bacteria that is most commonly found in legume nodules. These bacteria are able to use energy from the plant to change nitrogen from the air into a form that can be used by plants.

ii. NITROGEN FIXATION is the biological conversion of elemental Nitrogen (N_2) into organic combinations usable by living things. In this case, Bradyrhizobium spp. converts N_2 to a form that legumes can use.

iii. Because legumes can fix nitrogen they are the crops which have least dependence on this nutrient from fertilizers.

iv. Legumes can also be grown as a GREEN MANURE crop for the purpose of improving the soil fertility of a piece of land that will be used for growing other crops.

b. Legumes are the crop plants that contain the greatest amount of protein per pound. Neither whole dried milk or dried eggs have as much protein per pound as dried legumes. They are also very important for their oil content.

SHOW TRANSPARENCY OF PROTEIN LEVELS OF IMPORTANT FOOD CROPS

Protein levels of important food crops

Food Crop	Protein content
Soybean	42% to 33%
Peanut	30% to 25%
Wheat flour	13.5% to 9.8%
Potato	13% to 10%
Corn meal	9.4% to 7.0%
Whole rice	9.0% to 7.5
Polished rice	7.6% to 5.2%
Cassava	1.3% to 1.0%

2. **What are legumes used for?**

a. Legumes are commonly combined with cereal grains in food and livestock feed to increase protein.

b. In developed countries, processed soybean has become a popular meat substitute because of its low fat and low cholesterol.

c. When grown as a garden plant or by less developed cultures, legumes are cooked green, roasted and salted, or dried for later use in soup or stew.

B. Soybean (<u>Glycine</u> <u>max</u>)

1. **Where are soybeans grown?**

a. Soybeans are adapted to temperate climates with a warm growing season and a moist Summer.

b.They are tolerant of many soil types, but grow best on well drained, heavier soils.

c. The United States, Brazil and China are the largest producers, together growing 90 percent of the world's annual harvest.

d. The remaining 10 percent of the world soybean crop is produced by Europe, Russia, South Africa, Egypt and South America.

2. **How are soybeans grown?**

a. Soybeans are a row crop often grown in field rotations with corn or double cropped with wheat.

b. They respond well to phosphorus and potassium fertilizers, but nitrogen fertilizer is not always helpful.

c. The fields are commonly treated with a pre-emergence herbicide before planting. PREEMERGENCE HERBICIDE is a weed killer that controls plant growth before the crop seedlings appear above the soil surface.

d. Planting is done in rows 6-30 inches apart.

e. A combination of herbicide and close-planting controls most weed problems. Weed control is an important factor for harvesting by combine. A COMBINE is a farm machine that harvests, threshes, and cleans grains and legumes while moving over the field.

3. **What are soybeans used for?**

a. In the U.S., the majority of soybeans are used for oil.

i. 70 percent of all soybean oil is used for food products such as salad oil, margarine, and mayonnaise.

ii. 30 percent is used for industrial products including paint, varnish, and ink.

b. After the oil is removed, the remaining "protein cake" is most often used in poultry feed.

C. Peanut (Arachis hypogaea)

1. **Where are peanuts grown?**

a. Peanuts are grown throughout the tropics and subtropics, and in warmer areas of the temperate region.

b. The United States, India, China, and Brazil are the world leaders in peanut production.

2. **What are the two main types of peanuts?**

a. Virginia peanuts have larger seeds that remain dormant after reaching maturity in about 120 to 180 days.

b. Spanish peanuts have smaller seeds that may sprout after reaching maturity in about 90 to 110 days.

3. **How are peanuts grown?**

a. The seed peanuts are planted into light, sandy soils. Light soils are important for "pegging" and harvest.

b. The plant produces flower clusters that grow close to the soil surface.

c. After the flower is pollinated the growing stem pushes it below the soil. PEGGING refers to the growth of the peanut flower pedicel which pushes it below the soil.

d. The flowers develop fruit (pods and nuts) that grow and mature underground.

e. In most parts of the world all activities are done by hand, and nuts are hung to dry in the sun.

f. In mechanized systems seeds are often harvested before maturity and must be artificially dried.

III. Tropical Crops

A. Introduction

Three of the 15 major field crops in the world require a tropical climate for production. Sugar and Coconut will be described in this section. Banana will be addressed in the next chapter as a case study.

B. Sugarcane (<u>Saccharum</u> <u>officinarum</u>) is a member of the grass family (Graminae). The main sugar producers include Brazil, the Philippines, Cuba, Hawai'i, Fiji, and India.

1. **What are the growth characteristics of sugarcane?**

a. It is a short day crop of the warm tropical lowlands.

b. It requires a long, humid growing season of 12 to 18 months.

c. Large quantities of water are needed for maximum production. Sugarcane requires almost one ton of water (4,400 gallons) per pound of sugar produced.

d. The growing season is best followed by a dry period to allow sugar to accumulate in the plant stem.

e. Many hybrids have been developed for disease resistance and strong growth.

f. It is one of the worlds most productive crops, yielding more than 90 tons per acre.

2. **How is sugarcane cultivated and processed?**

a. Sugarcane is grown by sticking 8-12 month old sections of stem in the ground.

b. These cuttings grow adventitious roots and sprout from axillary buds.

c. The best yield comes from complete replanting after harvest.

d. Sugarcane is also commonly grown for a second and third year by the ratooon method of propagation. RATOON is the regrowth of a plant from its crown or stem.

e. Sugarcane is the tropical crop most fully adapted to mechanized agriculture. Commercial production usually includes soil testing, machine planting, irrigation, and heavy fertilization.

f. However, in less developed countries sugarcane is planted, cultivated, and harvested by hand.

g. The harvested cane is crushed between rollers to extract the juice. BAGASSE is the fibrous residue of sugar cane stems.

h. The juice is boiled or steamed, filtered, and crystalized into pure sucrose. The remaining liquid with its brown impurities is molasses.

C. **Coconut** (Cocos nucifera)

Coconut trees are long lived plants that will be productive for 60+ years when properly cultivated. Many coconut plantations on Pacific islands are overmature and require reestablishment to obtain maximum yields. This section will describe the steps in establishing a coconut plantation.

1. How are the best seeds selected?

a. Coconuts have the largest seeds of all plants.

b. It is important to select the best seeds for strong healthy plants.

c. Look for trees with many nuts, leaves and strong thick trunks.

d. Remove all nuts on the ground below these trees.

e. Return after 2 weeks and collect the nuts to be used for seed.

f. Use only large nuts that: have water and are well shaped (not uneven).

g. Collect twice as many nuts as needed to grow the plantation.

2. How is a coconut nursery managed?

a. Use the nursery to select early germinating, strong seedlings from selected nuts.

b. Find a level, sunny area with room for 3 ft. x 3 ft. space per nut.

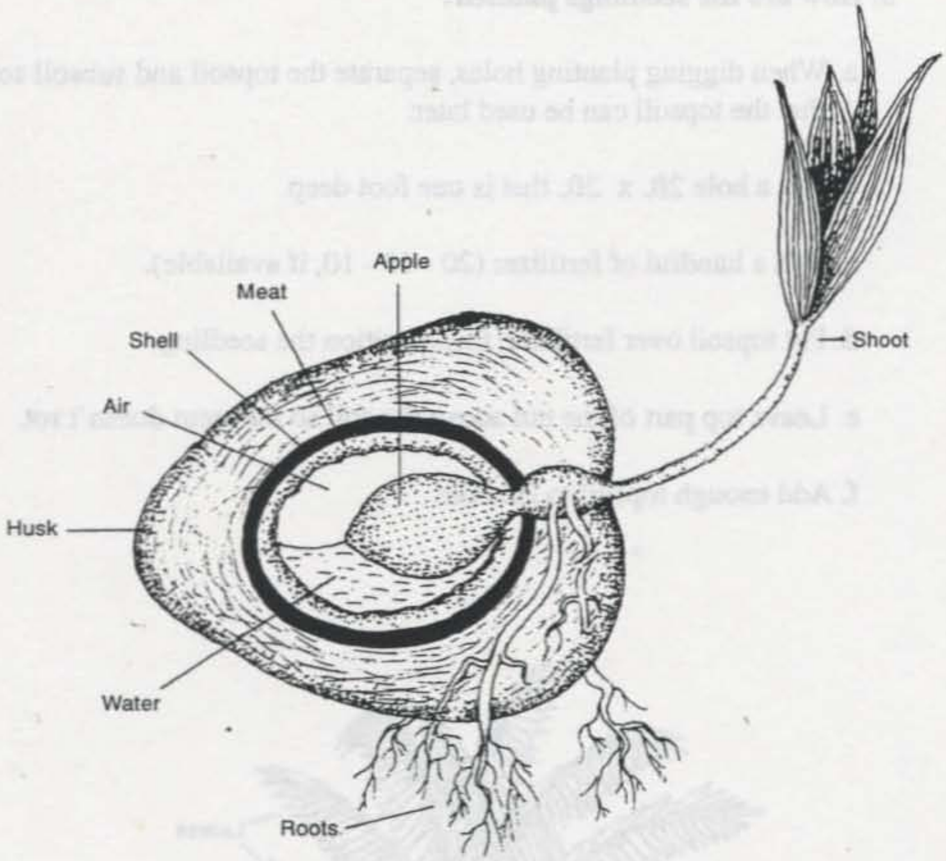
c. Make lines 3 feet apart with a shallow groove in the soil.

d. Set nuts in the groove 3 ft. apart with the broadest side up.

e. Cover with leaves and grass, then water everything each day.

f. As each nut germinates move it to one end of the nursery.

g. Seedlings are ready to transplant into the plantation when there are four to five green leaves growing on a strong, straight stem.



3. **What is the best way to select and clear a site?**

    a. Coconuts grow well at sea level to about 1200 ft. elevation, in areas with direct sun, plenty of rain, and well drained soil.

    b. Remove trees, cut brush and control weeds in large circles where each plant will grow.

    c. Save the cuttings for a mulch after planting.

4. **How should the seedling trees be spaced in the field?**

    a. Measure the field and mark each place for planting.

    b. If only coconuts are grown, spacing is in a triangle pattern 28 feet apart. This produces the largest number of plants per acre, allows for maximum sunlight interception, and limits weed growth.

    c. If cattle will be raised under coconuts, the trees should be spaced in a square pattern 30 feet apart. This method produces fewer plants per acre, but allows enough sun for good grass growth.

5. **How are the seedlings planted?**

a. When digging planting holes, separate the topsoil and subsoil so that the topsoil can be used later.

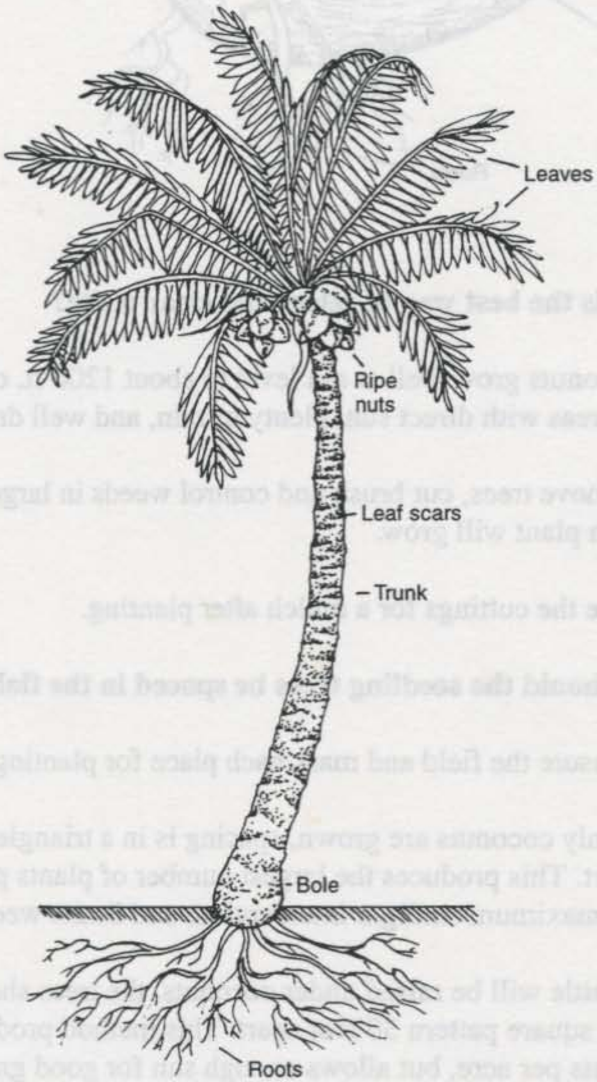
b. Dig a hole 2ft. x 2ft. that is one foot deep.

c. Add a handful of fertilizer (20 - 10 - 10, if available).

d. Put topsoil over fertilizer, then position the seedling.

e. Leave top part of the nut above the soil so the stem doesn't rot.

f. Add enough topsoil to fill hole.



Banana Production: A Case Study

5

Banana Production: A Case Study

5

Performance Objectives

Upon completion of this chapter each student should be able to:

A. Define the 12 terms related to banana production.

B Explain three reasons why bananas are a popular crop for Pacific island farmers.

C. List three reasons why banana roots are different than the roots of most crop plants.

D. Describe the differences between a sword sucker and a water sucker.

E. Identify the six main parts of the flowering stem of a banana plant.

F. Write a brief description for each of the three most important types of bananas.

G. List the seven key points for selecting the best site for a banana plantation.

H. Explain at least four practices used when properly clearing land for a banana plantation.

I. Explain the two main reasons that bananas are planted closer together than most other crop plants.

J. List three factors that affect the spacing of banana plants to optimize available sunlight.

K. List the four steps used to obtain a recommended spacing between banana plants.

L. Explain the recommended practices for controlling weeds in a banana plantation.

M. List three main benefits of a properly fertilized banana plantation.

N. Describe the best complete fertilizer mixture (and time of application) for banana production.

O. Explain two main reasons for desuckering banana plants.

P. Describe the appearance of a correctly desuckered banana plant.

Q. Describe nematodes and the damage they cause to banana plants.

R. Explain the three main ways of controlling nematodes in a banana plantation.

Chapter 5 objectives, continued

S. Describe weevil borers and the damage they cause to banana plants.

T. Explain three methods of controlling weevil borers in a banana plantation.

U. Describe how leaf spot diseases are caused and name the three important types that damage many banana plants in the Pacific islands.

V. Explain at least six key points about preparing and spraying fungicides to control leaf spot diseases.

W Describe the effects of bunchy top disease and how it is caused.

X. List the two effective ways to control bunchy top disease.

Terms

BELL- A cone shaped structure at the end of the flowering stem which is made up of the young bracts formed one around the other.

BIT- A large piece of a banana corm, containing at least one active eye or growing point, that is used for planting material.

BRACT- A large leaf-like covering that encloses each group of female and male banana flowers.

CORM- The true stem of a banana plant that forms a hard underground base.

DESUCKERING- The practice of cutting out the unwanted suckers from a banana plant.

FALSE STEM (pseudostem)- The part of a banana plant made of tightly packed leaf sheaths.

FOLLOWER- A large sucker that has not yet fully matured.

MAIDEN- A mature false stem that will soon flower and bear fruit.

PEEPER- A very young sucker with only small leaves.

SUCKER- A young plant that begins as a bud or "eye" growing from the corm.

SWORD SUCKER- A sucker with a strong false stem that is attached to the "mother" plant.

WATER SUCKER- A sucker with a weak false stem that is not attached to the "mother" plant.

I. Importance and Botany of Bananas

A. Introduction

Bananas are tropical lowland plants that originated in southeast Asia. They grow best in areas that have temperatures between 60° F and 85° F with well-distributed (minimum 4 inches/month) annual rainfall.

Bananas are classified in the genus Musa and then into four groups based upon the degree of interspecific crossing between M. acuminata and M. balbisana. Each group is composed of cultivars that have botanical and agricultural differences.

1. **Why are bananas important in the Pacific islands**?

a. Bananas fruits (cooked and ripe) are a staple food in local diets and the leaves are used for many purposes.

b. The plants are well adapted to the climatic conditions.

c. Bananas are a popular crop with farmers for three main reasons.

i. They are a source of ready cash at the local market.

ii. High returns for improved management. This means that increased labor will bring additional profits.

iii Bananas bear fruit at frequent intervals, about once every seven to nine months.

B. Botany

1. **How are bananas different from other crop plants?**

a. The roots of a banana plant are different for three reasons.

i. They are fleshy and easily broken.

ii. They do not grow very deep in the soil.

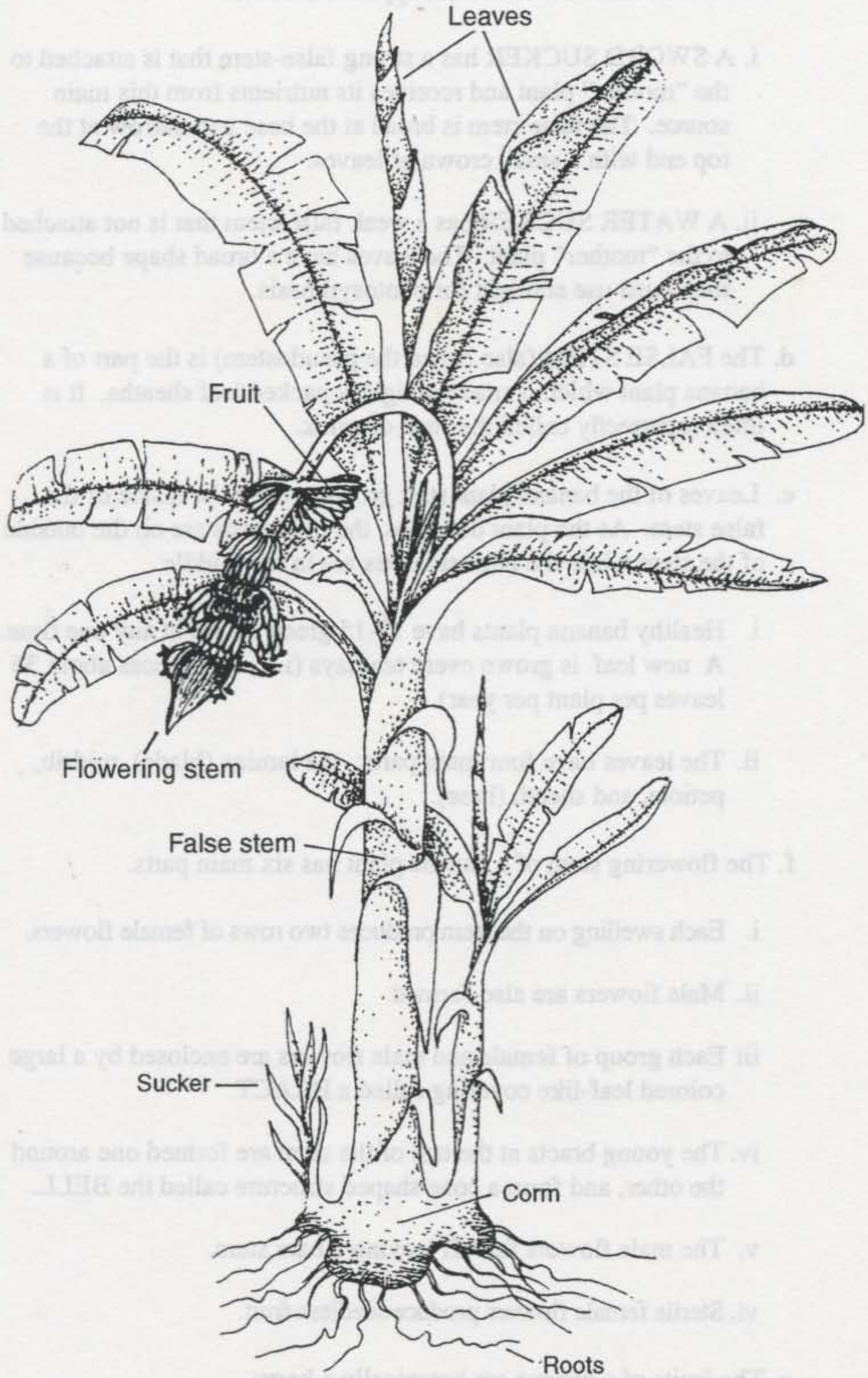
iii Banana roots are large in diameter and cannot grow around obstacles such as rocks in the soil.

b. The CORM is the true stem of a banana plant.

i. It is a hard underground base that produces 200-400 roots .

ii. The corm stores food and transfers nutrients, water and air between roots and leaves.

iii As the banana corm grows, new suckers form as part of the plant.



Seven main parts of a banana plant

SA

Examine the roots, corm, suckers, false stem, leaves, and flowering stem of a banana plant.

Draw the plant and label all main parts.

c. A SUCKER is a young plant that begins as a bud or "eye" growing from the corm. There are two types of suckers.

i. A SWORD SUCKER has a strong false-stem that is attached to the "mother" plant and receives its nutrients from this main source. The false stem is broad at the base and narrow at the top end with a small crown of leaves.

ii. A WATER SUCKER has a weak false-stem that is not attached to the "mother" plant. The leaves have a broad shape because they must use sunlight for photosynthesis.

d. The FALSE STEM (also called the pseudostem) is the part of a banana plant which is made of tightly packed leaf sheaths. It is often incorrectly called the stem or trunk.

e. Leaves of the banana plant start growing from the inside of the false stem. As the plant develops, the old leaves are on the outside of the stem while the newest leaves are in the middle.

i. Healthy banana plants have 12-15 green leaves at any one time. A new leaf is grown every ten days (i.e., it produces about 36 leaves per plant per year).

ii. The leaves have four main parts; the lamina (blade), midrib, petiole, and sheath (base).

f. The flowering stem of a banana plant has six main parts.

i. Each swelling on the stem produces two rows of female flowers.

ii. Male flowers are also formed.

iii Each group of female and male flowers are enclosed by a large colored leaf-like covering called a BRACT.

iv. The young bracts at the end of the stem are formed one around the other, and form a cone shaped structure called the BELL.

v. The male flowers fall off leaving a bare stem.

vi. Sterile female flowers produce seedless fruit.

g. The fruits of a banana are botanically a berry.

i. Each row of female flowers develops into a 'hand' of fruit which together make the banana 'bunch'.

ii. Time from 'shooting' the bunch to harvest is about 90 days.

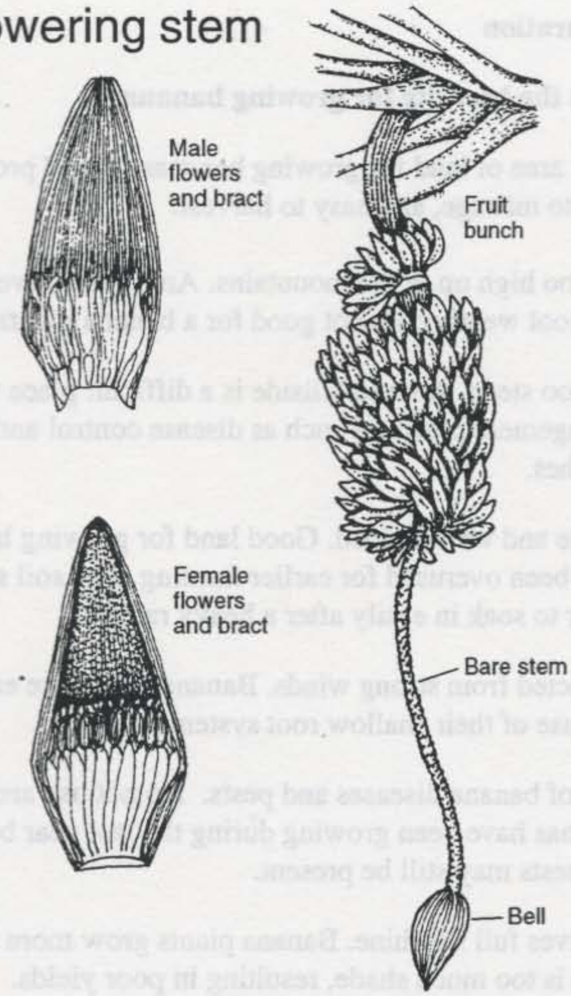
SA

Cut down an old banana plant at the base of the false stem. Look at the cross section to see all the leaf bases wrapped around each other. Pull these apart one at a time.

Dig up a corm and its suckers to see how they grow. Identify the sword suckers and water suckers.

Count the number of green leaves on a few healthy banana plants. Observe the newest and oldest leaves.

The flowering stem



2. **What are three important banana cultivars for Pacific islands?**

a Cavendish banana, 'Robusta' syn. 'Poyo', (AAA Group)
   i. The fruit of this type are long and slightly curved.
   ii. When ripe they are sweet and yellow-green.
   iii Unripened fruit are often harvested green for cooking.
   iv. This is the type of banana most often grown for sale.
   v. It requires water, fertility management, and disease control.

b. 'Mysore' banana, (AAB Group)
   i. The fruits are short but grow in large, tightly packed bunches.
   ii. When ripe they are sweet and bright yellow.
   iii It requires less water, fertility, or pest and disease control.

c. 'Bluggoe' bananas (ABB Group)
   i. The fruit are large, straight, thick, and angular at maturity
   ii. The hands are spread and widely spaced on the flowering stem.
   iii It is a starchy cooking banana.
   iv. It is suited to drier climates and has no disease problems.

SA

Look at a hand of fruit from each type.

A small planting of each type might be started on the school grounds

II. Banana Production

A. Site Preparation

1. What is the best site for growing bananas?

The best area of land for growing bananas should produce good fruit, be easy to manage, and easy to harvest.

a. Not too high up in the mountains. Areas that have too much rain and cool weather are not good for a banana plantation.

b. Not too steep. A steep hillside is a difficult place to use good management practices such as disease control and propping bunches.

c. Fertile and well drained. Good land for growing bananas must not have been overused for earlier farming. The soil should allow water to soak in easily after a heavy rain.

d. Protected from strong winds. Banana plants are easily blown down because of their shallow root system.

e. Free of banana diseases and pests. Do not use areas where any bananas have been growing during the last year because diseases and pests may still be present.

f. Receives full sunshine. Banana plants grow more slowly when there is too much shade, resulting in poor yields.

g. Close to a road. Roads are important for bringing planting materials, fertilizer and pesticide to the plantation, and also for taking the harvested banana bunches to the market or wharf.

After presenting this information; discuss and study different local areas to decide if each site would be good for a banana plantation.

2. What is the best way to clear a plot for banana planting?

a. Clearing should be done at the end of the dry season so that the site will be ready for planting during a rainy time.

b. Large trees can be cut with a chainsaw or axe and piled into heaps.

c. If the site is an old banana plantation all the old plants must first be destroyed. During the waiting period (one full year) immediately remove any suckers which develop from old banana plants.

d. Light bush is best cleared with a bush knife and the cut weeds left to rot into the topsoil.

e. The richest part of the soil is in the top three to six inches. The topsoil should not be disturbed more than necessary. For this reason never bulldoze land for a banana plantation.

Chapter 2 objectives, continued

T. Describe three ways soil affects water availability.

U. List six factors that affect transpiration.

V. Explain five negative effects of high precipitation on crop production.

W. Explain eight ways crop production practices can optimize crop growth under different precipitation conditions.

X. Name and describe three categories diffeent storm categories based on wind speed.

Y. Describe three air quality factors and their affects on plants.

Z. Describe three effects of air movement on crop production.

AA. Explain the three major contributing factors to global warming.

B. Crop Establishment.

1. **How is high quality planting material selected?**

New banana plants are grown by vegetative propagation.

a. Plant materials must come from disease and insect free plants.

b. The corms and suckers can be used as planting materials.

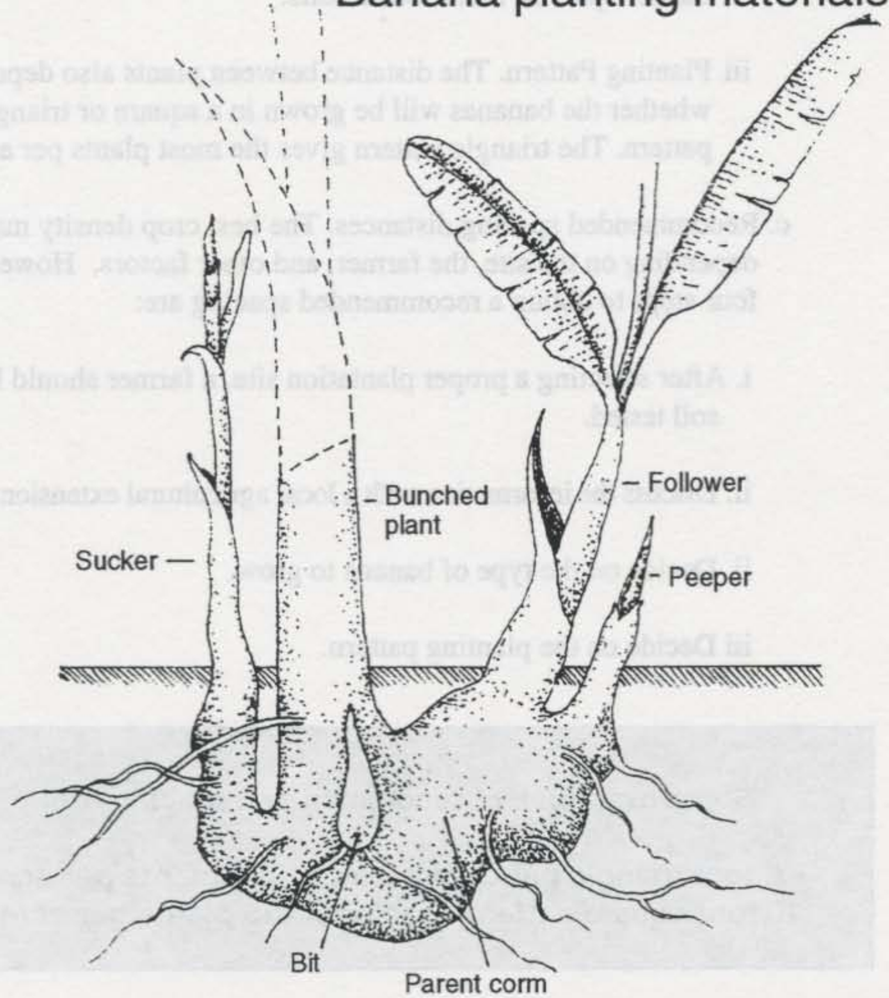
c Corms may be cut into large pieces, each with at least one active eye or growing point. Each piece is called a BIT.

d. A very young sucker with only small leaves is called a PEEPER.

e. Sword suckers are usually the fastest and strongest planting material. Water suckers should not be used.

f. FOLLOWERS are larger, older suckers that have not yet sent up a flowering stalk. They must be trimmed before planting.

Banana planting materials



Students should be given the opportunity to see and handle the different types of planting materials in the

2. **What is the best crop density for banana production?**

a. Bananas are planted closer than most crop plants for two reasons.

i. The roots of a banana plant grow very shallow in the soil and must compete for nutrients and water with the weeds growing around the false stem. For this reason, bananas are planted close together so that when fully grown their leaves will shade the ground and not allow weeds to grow.

ii. The roots of a banana plant are not long enough to compete for the same nutrients and water needed by other bananas growing close to them.

b. Three factors affect the distance between banana plants that will allow fully grown plants to shade the ground but not each other.

i. Size of the plant. Some cultivars of banana plants grow larger than others and need more space between them.

ii. Fertility of the soil. Some types of soil contain more nutrients and will grow larger banana plants. Bananas should be planted farther apart on more fertile soils.

iii Planting Pattern. The distance between plants also depends on whether the bananas will be grown in a square or triangle pattern. The triangle pattern gives the most plants per acre.

c. Recommended spacing distances. The best crop density may vary depending on the site, the farmer, and other factors. However, the four steps to obtain a recommended spacing are:

i. After selecting a proper plantation site, a farmer should have the soil tested.

ii. Discuss the information with a local agricultural extension agent.

ii. Decide on the type of banana to grow.

iii Decide on the planting pattern.

Some examples of recommended spacing are:

8.5 foot triangle pattern spacing = 700 plants per acre
10 foot square pattern spacing = 435 plants per acre.

III. Managing a Banana Plantation

Many banana plantations may increase profits if additional management practices are used. The proper management of a banana plantation can make the difference between success and failure.

A. Weed and Fertility Management

1. What are the most effective weed control practices?

Weeds must be closely managed until the bananas grow large enough to completely shade the ground.

a. During the first four months after planting:

i. A three foot diameter around each plant should be clean-weeded by hand every month. This is called ring weeding.

ii. The area between the banana lines should be slashed or sprayed every two months.

b. From four months until the banana lines completely shade the ground:

i. Each banana plant should be ring weeded in a three foot diameter every two months, or sprayed to keep free of all weeds.

ii. The area between the banana lines should be cleared every three to four months.

2. What are the best soil fertility practices?

The results of a soil test will describe the fertility conditions at the time of crop establishment and provide recommendations for ongoing management.

a. All types of bananas require fertilizer for highest production.

b. Three major benefits of properly fertilized banana plantations are:

i. Increased yield of fruit per acre.
ii. Shorter time to harvest.
iii. Greater resistance to disease.

c. Potassium, is the most needed nutrient followed by Nitrogen, then Phosphorus. The best ratio for a complete (N-P-K) fertilizer will be lowest for the middle number and highest for the last (i.e., 10-5-20).

d. Banana plants require a continuous supply of nutrients and should be fertilized every two months.

e. The false stems and leaves of bananas contain many nutrients.

i. After a bunch is harvested, the false stem should be cut down, chopped into pieces, and spread between the rows of plants

ii. In most cases, old leaves should also be left to decay and return to the soil.

f. Soil and leaf tests should be taken each year.

B. Desuckering

Desuckering is one of the most important jobs in managing the plantation. Yet it is the practice which is most often not done.

1. **Why should bananas be desuckered?**

a. DESUCKERING is the practice of cutting out the unwanted suckers from a banana plant.

b. Many farmers think that more suckers will yield more fruit, but this is not true.

i. When banana plants are not desuckered the extra suckers will compete for nutrients and water in the soil. This will make the main stem and its fruit small.

ii. When banana plants are not desuckered there are often more pest and disease problems.

SA

Students should be taken to a banana plantation, shown the proper method of desuckering and allowed to practice under supervision.

2. **How should a banana plant look after proper desuckering?**

The plant should have three false stems after desuckering .

a. A main stem which is flowering or bearing fruit.

b. A MAIDEN is a false stem that will soon flower and bear fruit.

c. A follower or peeper that will grow to become a maiden.

3. **When should desuckering be done?**

a. The plantation should be inspected for desuckering every two months. Remove unwanted suckers when they are found.

b. A banana plant should not be desuckered just before it is about to flower. This will shock the plant and flowering may be delayed.

C. Pest Management

1. **What are nematodes and how are they controlled?**

   a. Nematodes are pests that live in the soil and damage the roots of banana corms, eventually killing the whole plant.

   b. Nematodes are too small to be seen without a microscope.

   i. Their damage is seen by inspecting roots of unhealthy plants.

   ii. The roots may have small red/black holes which have been infected by fungus; or the roots may be swollen in odd shapes.

   c. There are three main ways of controlling nematodes.

SA

Students should look at examples of pest damage to banana roots, corms and fruits.

Nematode Control

Before planting:

i. Use ground never planted to bananas or wait at least one year after destroying old banana plants.

ii. Soak trimmed and pared planting material in hot water (56° C) for five minutes.

After Planting:

iii. Spread a chemical nematicide on top of the soil around each plant, every six months.

2. **What are banana weevil borers and how are they controlled?**

   a. Banana Weevil borers are a type of black beetle (about 1 inch long).

   i. They dig into banana corms above the ground and lay eggs in the hole.

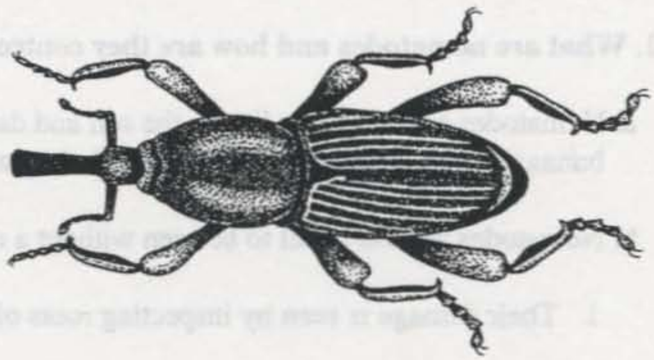
   ii. The eggs hatch into white caterpillars that bore into the corm causing it to rot and killing the banana plant.

   b. Weevil borers can be seen by inspecting the banana corms for holes and /or caterpillars.

SA

•Students should be taken to a banana plantation where each method of pest control can be demonstrated and practiced.

Banana Weevil Borer



c. There are three ways of controlling banana weevil borers:

Before Planting:

i. Carefully inspect all planting materials. Destroy any materials that may be infested with weevils, their eggs or caterpillars.

After Planting:

ii. A trap can be made by leaving a cut piece of corm lying on the ground. Weevils will come to live under this.

iii Spread a chemical nematicide on top of the soil around each plant every six months. If this treatment has been done for nematodes no other control is needed.

3. What are banana aphids and how are they controlled?

a. Banana aphids are very small (1/16 of an inch) flying pests.

b. Bunchy Top disease.

Banana Aphid

D. Disease Management

1. **What are leaf spot diseases and how are they controlled?**

a. Leaf spot diseases are caused by fungi that are spread from leaf to leaf by tiny spores, which may be carried by the wind.

b. These spores can germinate on a leaf and grow inside the leaf through its air pores (stomata).

c. There are three important leaf spot diseases:

i. Sigatoka Leaf Spot disease looks like pale streaks on the young leaves. These turn into long narrow dead streaks with black edges. Cavendish bananas get this disease when very young.

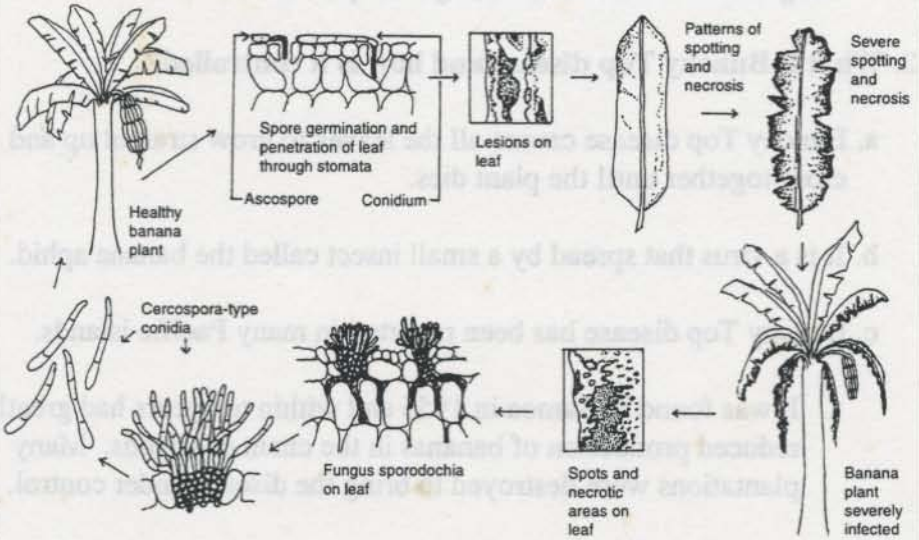
ii. Black Leaf Streak appears on the underside of young leaves as pale yellow or brown streaks with black edges.

iii. Cordana Leaf Spot disease symptoms look like egg-shaped spots which turn into dead patches with yellow edges.

SA

Study examples of banana leaves damaged by the different types of leaf spot on your island.

DEVELOPMENT OF SIGATOKA DISEASE OF BANANA CAUSED BY MYCOSPHAERELLA MUSICOLA



d. All of the leaf spot diseases kill leaves needed by the banana plant for photosynthesis.

i. Infected plants are very slow in producing fruit and will die if the disease is not controlled.

ii. Control is achieved by spraying with fungicide.

d. There are two basic rules in preparing fungicide to control leaf spot.

i. All spray mixtures should include an emulsifier to keep the fungicidal powder dissolved evenly throughout the mixture.

ii. Misting oil is always included to help the spray stick onto the banana leaves.

e. There are two basic rules for spraying fungicides.

i. Spraying should only be done in the cool of the day, during the early morning or late afternoon hours.

ii. Spraying should never be done in windy weather.

f. Timing is very important in spraying fungicide to control leaf spot .

i. New plantings should be sprayed when three to four months old.

ii. A regular spraying schedule is followed every two weeks during dry weather.

iii. It may be necessary to spray more often during the rainy season.

e. Your agriculture extension office can help in selecting the best fungicide to use for controlling leaf spot diseases.

2. **What is Bunchy Top disease and how is it controlled?**

a. Bunchy Top disease causes all the leaves to grow straight up and close together until the plant dies.

b. It is a virus that spread by a small insect called the banana aphid.

c. Bunchy Top disease has been reported in many Pacific islands.

i. It was found in Samoa in 1956 and within ten years had greatly reduced production of bananas in the chain of islands. Many plantations were destroyed to bring the disease under control.

ii. Hawaii has only recently reported the Bunchy Top disease. Plantation-wide eradication is still an important means of control in the state.

iii. There are only two effective ways to control bunchy top disease in bananas:

- Use only disease free planting materials.
- Destroy any infected plants.

Crop Production Reports

Cassava

Taro

Yam

Avocado

Mango

Papaya

Bell Pepper

Chinese Cabbage

Cucumber

Crop Production Report: Cassava

Scientific Classification
Family: Euphorbiaceae
Scientific Name: Manihot esculenta

Botanical Description
Cassava is a shrub that grows three to twelve feet high depending on the cultivar and growing conditions. The stem is woody at the base, but becomes softer towards the tips of the stems. The main stem is often branched, and cultivars can be distinguished by their branching pattern; few branches vs. many branches, or branching low vs. branching high.

Underground, the cassava plant (if grown from a stem cutting) has a fibrous root system. This root system penetrates down into the soil 20 to 40 inches. A few (less than 10) of these fibrous roots develop into storage roots that are usually attached to the stem by a neck. The tuberous root is generally fattest at the stem end and tapers down to a very thin tip. The growth of the tuberous root is very different from that of most "root crops" which are actually modified stems. This allows cassava to penetrate hard soils better than yam, taro, or sweet potato. The long thin fibrous root grows to its full length first, while penetrating the soil. Then the diameter of the root increases as it fills with starch until reaching maturity.

History/Origin
Cassava has not been found in the wild. It is believed to have originated in Central America and Brazil. Cassava was introduced into the Pacific in relatively recent times. Today it is grown in most Pacific islands.

Cassava is easy to grow, and for this reason its production is on the increase in many areas. In the 20 years from 1965-1984 the world wide cassava production increased by 330 percent.

Uses
Cassava is a good source of starchy carbohydrates for energy. It is also a good source of dietary fiber. Cassava roots contain vitamin C, and yellow varieties contain some beta carotene . Although the tuberous roots are the main reason why cassava is grown, the leaves of cassava are also eaten or used as animal feed.

Cassava meal can be substituted for corn at levels of up to 30 percent in broiler chicken feed. It can also be economically fed to pigs and other livestock, reducing the need for imported feed grains.

Environmental Requirements
Cassava grows best in locations where the rainfall is 40 to 55 inches per year and well distributed, but cassava will grow with 100 inches or more of annual rainfall.

Cassava is also a valuable crop in places where the rainfall is low, or irregular. It is drought tolerant, and can survive four to six months of dry weather. It will grow with as little as 8 inches per year. The only time that cassava cannot tolerate drought is during the first two or three weeks after planting. Planting should always be done during a rainy period or irrigation should be provided.

Cassava grows best in light soils which are well drained. It will yield better than most crops on acid soils. It does not grow well in soil with a high pH, such as coral sand. It is not well suited to atolls or limestone islands.

Cassava grows well on low fertility soils. In high fertility soils it tends to produce more vegetation than tubers. However, sufficient P is needed to produce large tubers.

Propagation
Unlike sweet potato or yam corms, eyes or buds never develop on cassava tubers no matter how long you store them nor how you cut them. Because the tuber will not sprout, it cannot be used for propagation. Hardwood cuttings of the lower stems are used for planting material.

As a general rule, cuttings 7 to 10 inches long are recommended. It is important that each cutting have at least three nodes, but cuttings with five to seven nodes are better. This means that cultivars with very long internodes may require longer cuttings.

Thin cuttings produce weak plants. As a general rule, cuttings should be at least half the diameter of the thickest part of the stem for the specific cultivar being grown.

Cuttings taken from 8 to 18 month old plants are best. Cuttings from the older, more mature parts of the stem give the highest yields compared to those taken from younger parts of the stem. Very old, woody stems are not good planting material. Cuttings should only be taken from disease free plants.

Cuttings should be prepared as close to planting time as possible. If you can not plant immediately after harvesting, leave the stems in long pieces and cut them into short lengths before planting. Store the long lengths in a shady place with high humidity. Stems stored standing upright with their basal ends in soil will begin to form roots which will help keep them alive.

Cultural Practices

Cassava can be planted on flat soil or into ridges or mounds. Mounds/ridges should always be used if the soil is poorly drained or waterlogged. Harvest is easier if mounds or ridges are used.

For a monocrop of cassava the recommended space between plants is 3-4 ft. The distance between rows may be from 2-4 ft. Cultivars that are low branching and contain many branches need wider spacing than cultivars with a few high branches. Narrow-leaved cultivars can generally be planted closer than those with broader leaves. Wider spacing is needed when soil fertility and rainfall are high. Spacing should result in plants that touch each other and shade the soil within four months after planting.

Cassava stem cuttings can be planted vertically, horizontally, or slanted. If planting vertically or slanted, 1/2 to 2/3 of the stem cutting should be below ground. If planted horizontal the entire cutting is about 3 inches below ground.

Under low rainfall conditions horizontal planting is recommended. Under high rainfall conditions vertical or slanted planting should be used because horizontal cuttings tend to rot in wet soils. When lodging is a problem, horizontal or slanted planting is recommended. Horizontal planting is the easiest to adapt to mechanized practices.

Where weed pressure is heavy, vertical or slanted planting is preferred because horizontal plantings are slower to emerge. Weed control in cassava is most important during the first three months after planting. If weeds are not controlled during this period, irreversible yield losses will occur. Mulches of organic materials are recommended to control weeds and maintain soil moisture

Cassava is often grown as the last crop before the land is returned to bush fallow. This is because its vigorous root system can extract soil nutrients deep in the soil. However, repeated cropping under these conditions can thoroughly deplete the fertility so that native fallow plants can not return. For this reason, a maximum of three continuous cassava crops is recommended prior to fallow.

Pests and Diseases

Cassava has few pests or diseases. Rats are the most serious pest of cassava because they dig down and eat the cassava roots in the field. Good sanitation around fields and the use of traps or poison baits can keep rat populations down.

Bacterial blight, is the largest disease problem of cassava. Infected leaves drop prematurely, causing losses in yield. Care should be taken to use only disease free planting material to prevent introduction or spread of this disease.

Harvesting and Storage

Cassava is ready for harvest six to 15 months after planting, depending on the cultivar and the growing conditions. Low rainfall and poor soil may require as long as 24 months to produce a reasonable yield. A few cultivars in the Pacific region are reported to be ready for harvest in as little as three or four months.

In the Pacific all harvesting is done by hand. Yields average 2-3 tons per acre, but yields as high as 10 tons/ac. can be obtained.

Cassava stores very well in the field. However, if harvested after maturity it will be more fibrous. Rotting during field storage can be a problem if the soil is poorly drained or flooded.

After harvest, cassava roots can be stored for only one to three days before they begin to develop black streaks. Therefore it is best to harvest only as many tubers as can be eaten, marketed, or processed in a few days.

The tubers can be stored for approximately two weeks if they are packed in wooden boxes filled with damp sawdust or paper (do not use sawdust from treated wood—it is poisonous). The roots can also be peeled and frozen for longer storage.

Processing

Some varieties of cassava contain hydrocyanic acid (HCN), a substance that may be toxic if the cassava is not properly prepared. The varieties of cassava that contain toxic amounts of HCN are known as "bitter" varieties. Varieties low in HCN are known as "sweet" varieties, and need no special treatment other than cooking to prevent toxicity.

HCN is soluble in water, and also evaporates readily in air at temperatures above 28 C. Grating of cassava roots, followed by repeatedly soaking in fresh water and draining, or drying in the sun are two very effective methods of removing HCN from cassava. The grating and leaching method is more effective at removing HCN than drying.

References

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Wilson, J.E. 1988. Teachers Manual for a Course on Root Crop Production in the Pacific. Honolulu: University of Hawaii, SPRAD Project.

Thaman, R.R. and Thomas, P.M. 1985. "Cassava and Change in Pacific Island Food Systems" in Food Energy in Tropical Food Systems. New York: Gordon and Breach

Crop Production Report: Taro

Scientific Classification
Family: Araceae
Scientific Name: Colocasia esculenta

Botanical Description
The above ground shoot of the taro plant is made up of leaves. Each leaf consists of a long petiole and blade. Colocasia leaves point downward. The leaf is said to be peltate because the petiole is attached to the blade at a point inside the margin of the blade.

The stem of Colocasia is underground. It is a storage stem called a corm. The corm has leaf scars where the old petioles were attached. Near each leaf scar is a lateral bud. These buds give rise to cormels or suckers, which represent the lateral branches of the plant. The root system is fibrous, and generally very shallow with most of the roots located in the top one foot of soil.

History/Origin

Colocasia esculenta originated in Southeast or South central Asia, and was one of the first plants domesticated for crop production in that region. It was spread throughout India, China, and Japan, then later to the Pacific islands. Taro has been grown in the Pacific for about 2000 years.

Local Cultivars/Types

There are numerous cultivars of Colocasia in most Pacific islands. The cultivated varieties are commonly described by the color of the leaf, veins and corm flesh; by the shape and number of fully developed leaves; and by the taste and texture of the corm.

Uses

Taro is a staple food in many Pacific countries, and is prepared in different ways to produce traditional dishes. The starchy corm may be boiled, roasted, or mashed and fermented. The vitamin rich leaves are cooked as a vegetable.

Environmental Requirements

Colocasia can be grown in a range of environments and management systems. It is commonly produced as either a upland, rain-fed crop or in wetland paddies.

Upland methods of raising taro require at least 80 inches of rain evenly distributed throughout the growing period. Wetland taro grows best when planted in an area that receives a continuous supply of moving water.

Colocasia can grow in light shade. It is usually grown as a monocrop, but can be found planted amongst coconuts, bananas, citrus, cocoa, and other crops.

Propagation

Taro is propagated vegetatively, and several different types of planting materials are used. The headsett is made up of the apex of the corm and the attached petiole bases. Large suckers are also used as planting material. For rapid multiplication, cormels, pieces of corm, and stolons can also be used.

Taro can be propagated from seed, but this is only done for breeding purposes. It is not a good method of propagation for farmers because taro seed does not breed true.

Cultural practices can be used to affect the number of suckers produced on a plant. Planting taro shallow, in high nitrogen soil, with a wide distance between plants increases the number of suckers. The opposite conditions or practices will decrease the number of suckers.

Larger planting material will usually produce larger corms and higher yields. Small setts produce lower yields and may not survive a long dry period. The size of planting material refers to the diameter of the base of the headsett or the sucker.

Farmers often replant headsetts and suckers after harvesting the main corm. Taro can be planted year round when wetland or heavy-rain conditions exist. In areas with a definite dry period, it is best to plant at the start of the wet season, before the heavy rains arrive.

Cultural Practices

Taro can be grown using a variety of cultural methods. A planting stick is used to dig a hole is in many places. Mechanical planting is also used, but the field must be relatively flat and free of rocks or other obstructions. Planting depths vary depending on the method used. Generally taro is planted between one and 1.5 feet deep.

Recommended planting distances for monocrop taro production in upland conditions with fertile soil are 2ft x 2ft, or 2ft x 3 ft. Spacing should be wider if soil fertility is low, rainfall is low, or more suckers are needed. Wider spacing will increase the size of harvested corms on each plant, but decrease the total yield of pounds per acre.

Close spacing helps to control weeds so that less hand weeding and/or herbicides are necessary. The taro crop should be kept free of weeds during the first three months after planting. At that time the taro leaves shade most of the ground and weeding is not required.

Two months before harvest, the taro leaves become small and short. During these last months, weed control may again be required. This must be done with care because pulling the weeds can negatively affect the corm quality.

Fertilizer may be necessary to grow taro in soil that is low in nutrients. 20-10-10 fertilizer will meet most needs. Some farmers do not use fertilizer on taro because they think it will have a negative affect on corm quality. This will only happen if fertilizer is applied too late in the growth cycle.

When taro is grown on fields that have been cropped several times, it usually responds well to nitrogen. A general recommendation is 45-90 lbs. of N per acre, split in thirds and applied at five, 10, and 15 weeks after planting.

Taro also has a high potassium requirement. When soil is K deficient, about 60 lbs/acre can be broadcast at planting or split into two applications, one at planting and one 10 weeks later.

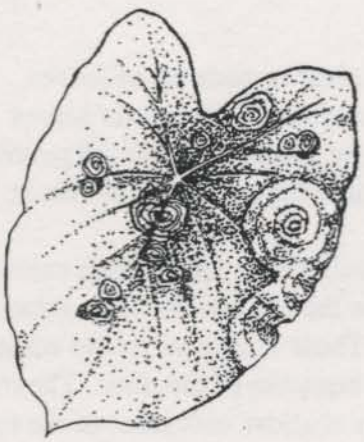
Phosphorus may also be applied at planting time, and a recommended amount is 45 lbs/acre.

Pests and Diseases

There are two main diseases that affect taro in the US affiliated Pacific islands. These are Taro Leaf Blight and Pythium rot.

Taro Leaf Blight is caused by a fungus, Phytophthora colocasiae. It occurs in, Samoa, Hawaii, and some islands of Micronesia.

Leaf Blight is introduced by infected planting material, and spread by wind driven rain. This disease attacks the taro leaves and can destroy them completely. It can also affect the corm, causing it to rot.



Taro leaf blight can be controlled by practicing crop rotation, using clean planting materials, removing and burning infected leaves.

Pythium rot is a fungus which attacks and kills the roots of the plant, causing wilting, corm rot, and sometimes death. Preventative practices include the use of clean planting material and resistant cultivars, avoiding poorly drained soils, and using preplant chemical controls. Once the Pythium fungus has contaminated the soil it is difficult and expensive to control. A five year fallow period is recommended for infested fields.

The three major insect pests of taro are armyworms, taro planthoppers, and taro beetles.

Armyworms occur throughout the Pacific. The young caterpillars strip the upper surface of the leaf. Older ones cause extensive leaf damage.

Smashing the egg masses before they hatch will quickly eliminate large numbers of the pest. If caterpillar infestation is light, handpicking and killing them is recommended. Chemical spraying can be used if the infestation is heavy.

The taro planthopper sucks the plant's juices, and heavy infestations cause the plant to die. A biological control, (Cyrtorhinus fulvus), is available that preys on planthopper eggs. Chemical control is possible but not generally economical.

The taro beetle makes tunnels in corms as it feeds, making the corms unmarketable. The beetle will attack the growing point of the plant, and thus kill it. This pest is not currently found in the US affiliated Pacific, but does exist in other nearby islands. The beetles can be transported within a number of host plants including; taro, banana, sweet potato, head cabbage, and pineapple. Host plants should not be introduced from infested areas.

Harvesting and Storage

Most cultivars of Colocasia grown in the Pacific islands mature in 7 to 11 months. The corms are ready for harvest when new leaves of the main plant are small with shorter petioles. Harvesting is done by hand. The main corm is loosened and pulled out.

At this time the suckers can also be harvested to plant another field, or left in place and mounded up to produce a second crop.

Care should be taken not to damage the corm during harvest or transport, as this promotes rot which reduces storage time. Mature corms can be stored for one or two weeks after harvest.

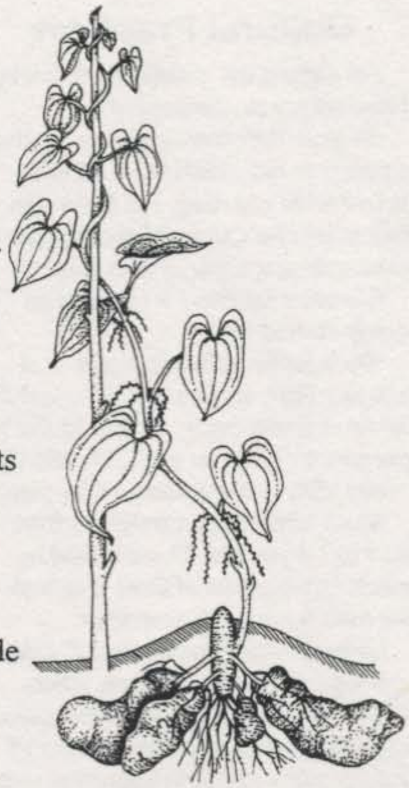
References:

Lambert, Michel (Ed.) 1982. Taro Cultivation in the South Pacific. Noumea, New Caledonia: South Pacific Commission.

Purseglove, J.W. 1988. Tropical Crops: Monocotyledons. Singapore: Longman Singapore Publishers.

Wilson J.E. 1988. Teacher Manual for Root Crop Production in the Pacific. Honolulu: University of Hawaii - SPRAD Project.

Crop Production Report: Yam



Scientific Classification

Family: Dioscoreaceae
Scientific Names: Disscorea spp.

There are may different species of edible yams in the genus Dioscorea. Four important species in the Pacific islands are:

D. alata ....has a square shaped stem that twists to the right. The leaves are heart-shaped.

D. nummularia .. has thorns only at the base of the plant, and the stem twists to the right. The leaves are heart-shaped.

D. esculenta ...... has thorns growing along the entire stem, which twists to the left. This plant has small heart-shaped leaves. When very young, the leaves are covered with a fine hair.

D. pentaphylla ... has thorns growing along the entire stem, which twists to the left. The plant has compound leaves made up of three to seven leaflets.

Botanical Description

The above ground part of a yam plant is a vine made up of the stem and leaves. The stem is not erect, and climbs on stakes, trees, or other objects. It does not have tendrils, but climbs on objects by twisting around them either to the left or right. The below ground portion of the plant is made up of a corm, tubers, and roots. The tubers grow from the corm which is located at the bottom of the stem. Fibrous roots grow from both the corm and the tubers. At harvest time the tubers are dormant and remain so for one to six months.

History/Origin

Yams may have originated in both the old and new worlds. Evidence has been found of their cultivation in ancient India and China. Spanish explorers to South America reported yams to be an important crop.

Local Cultivars/Types

There are many different regional cultivars of the yam species described above, each with a local name. The tuber flesh color may be white, yellow, or purple depending on the cultivar.

Tubers of some cultivars are difficult to dig up because they are large, very long, branched, and irregular in shape. The tubers can reach more than 100 pounds but are usually harvested when they reach two to six pounds. Other cultivars produce clusters of approximately 5-15 small tubers which are easy to dig up.

Within D. nummularia there are many different cultivars with local names meaning "hard" yam or "strong" yam. "Hard" because the flesh is drier and has a hard texture after cooking, or "strong" because the growing tubers can penetrate compacted, untilled soils better than other species.

Uses

Yams are the primary staple food crop of many Pacific islanders. The tubers are edible, and may be baked, boiled, fried or grated to prepare traditional dishes. Yams have an important role in some Pacific island cultural activities.

Environmental Requirements

Yams require year round warm temperatures with annual rainfall of at least 45 inches. Some types are adapted to areas with a distinct dry season.. They also require good drainage and won't grow well in constantly wet soils.

Propagation

Four different types of planting materials may be used. They are listed here in order of the most to least productive:

- Whole small tubers.
- The second harvest of tubers from yam plants they have been "milked."
- The head end of large tubers cut in pieces.
- The middle or tail pieces of large tubers.

Whenever a tuber is cut the chances of rot are increased and the pieces should be dusted with fire ash for protection.

Planting yam tubers in hills will provide better drainage and make harvesting easier. Yams are best planted at the beginning of the rainy season but can be started at other times if a thick cover of mulch is put on top of hills.

Cultural Practices

For highest net yields, the following practices are recommended:

•Prepare the planting site by digging a trench or individual holes 12 to 18 inches wide and deep. Fill these with a mix of compost, manure and legume plant cuttings; covered with soil.

•No other fertilizer is required on newly cleared land.

•On infertile soils add P and K at planting time, using a rate of 15 and 80 lbs./acre respectively. Apply 35 lbs. N per acre three times; at 10, 14, and 18 weeks after first sprouting of the plants.

•Plant whole tubers weighing from 0.33 to 1.5 pounds. These should be planted at intervals of three feet, with the rows three to 10 feet apart.

Larger planting materials and wider spacings will producer larger tubers. These may be of important ceremonial value. However, a greater quantity of smaller yams results in higher net yield.

Vines can be grown on man made trellises, trained to climb forest trees, or allowed to crawl on the ground.

Weed control is very important during the first four months. Staking or training yams makes weed and disease control easier. It also increases the size and total yield.

Disadvantages of staking include the increased time/money invested, and susceptibility to wind damage.

Pests and Diseases

Yams are subject to a number of insect pests. Rose Beetles can cause serious leaf damage. The African Snail eats the leaves and stems of young, sprouting plants. The Papuana Beetle eats the yam tubers.

Anthracnose (dieback) is the major disease of yams. Anthracnose is a fungal disease that can kill leaves and the entire plant. Some steps can be taken to minimize the chance of infecting a yam crop:

•Plant yams where the morning sun will dry the leaves.

•Don't remove weeds by hand or hoe while leaves are wet.

•Grow the yams on stakes to keep them off of wet ground.

•Use fungicide if necessary.

Harvesting and Storage

Yams are usually harvested after the vines die, 6 to 12 months after planting. Some species like D. nummularia may be grown for two to three years before they are dug. They can be harvested while still growing.

Harvesting yam tubers from a growing plant is called milking. The first harvest is done when the tuber is large enough to be used and the vine is alive and healthy. The soil is carefully dug away from one side of the tubers and roots, and the largest tuber is cut off, leaving the corm and small tubers. Then the soil is put back around the roots, so that the plant will continue to grow.

After harvest, most yam varieties can be stored in a cool shaded place with good air movement for one to five months,.

When harvesting and transporting yams, handle them carefully to avoid breaking the tubers or scratching the skin. It is also important to leave a protective layer of soil around the tubers and avoid strong sunlight, which damages the skin and starts rot.

References:

Migvar, L. 1968. How to Grow Taros, Yams, Cassava, and Sweet Potatoes. Saipan: Trust Territory of the Pacific Islands, Division of Agriculture

Purseglove, J.W. 1988. Tropical Monocotyledons. Singapore: Longman Singapore Publishers.

Wilson, J.E. 1988. Teachers Manual for a Course on Root Crop Production in the Pacific. Honolulu: University of Hawaii.

Crop Production Report: Avocado

Scientific Classification

Family: Lauraceae
Scientific Name: Persea americana

Avocados are a member of the Lauraceae family, commonly known as the Laurel family. This family contains approximately 2,000 species in 47 genera that grow mostly in tropical or subtropical regions and are often aromatic. There are approximately 50 species in the Persea genus.

Botanical Description

Although avocado cultivars show great differences there are some botanical similarities. Most avocado trees are evergreen (although some are semi-deciduous) with brittle branches. The branch shoots grow in flushes which occur several times a year. Mature trees can be more than 60 feet high, but grafted plants are usually shorter

An enormous numbers of flowers are produced on multibranched inflorescence, but fruit set is often poor. The flowers of avocados are small and perfect, with 12 stamens—nine of which are functional. The flowers are single pistil, one carpel with one ovule. Stamens and pistils mature at different times.

Avocado fruit is classified as a berry. Fruits are about 1 to 3 pounds in weight. Fruit skin color may be pale yellow, green, reddish, or purple when ripe. Immature fruits are almost always green. The flesh is yellow or yellow-green and soft like butter when ripe.

Races and Cultivars

Avocados can be classified by their "race"—a system of classification developed 50 years ago. This system is somewhat less helpful today—due to crossbreeding—but nonetheless useful in characterizing avocados.

Mexican avocados grow well at higher elevation and are cold hardened. Their small, smooth, thin-skinned fruits ripen in six to eight months. Mexican avocados have the highest oil content.

Guatemalan avocados are less resistant to cold. Their large, rough skinned fruits mature in nine to 14 months on long stalks. Seeds are small and tight in the fruit cavity. Fruits have a medium oil content of about three to 15 percent. Itzamna, McDonald, and Linda are Guatemalan cultivars grown in Hawaii.

West Indian avocados are well suited to warm low tropics, but the fruits are more subject to sunscald than other races. The fruit size of West Indian avocados is variable. *Pollock* is a West Indian cultivar important in Florida.

Most of the best cultivars are interracial hybrids. *Fuerte* and *Hass* are Mexican-Guatemalan crosses grown in California. In Florida two top cultivars are *Lula* and *Booth*, both Guatamalan-West Indian crosses.

History/Origin

The avocado was among the first of the wild plants used by early Central American civilizations. The three races of avocados originated in different areas of the highlands in Mexico and the Andes mountains as far south as Chile. Guatemalan avocados are native to the highlands of Central America, particularly Guatemala, Mexico, and Nicaragua, while the West Indies race is native to sea level regions in Central America (not the West Indies).

Uses

Compared with most fruit, avocado is high in protein and vitamins. The buttery flesh is eaten as a sandwich spread. The oil is used for cosmetics.

Environmental Requirements

Avocado trees grow well in a wide range of soil types if they have good drainage. They are intolerant of saline conditions. High winds can be very damaging to the brittle branches.

Each race has adapted to specific climatic conditions. West Indian avocados produce well in the tropics where the other two races rarely flower or fruit. However they do very poorly in drier, subtropical climates.

Propagation

Avocado seedlings do not usually produce fruit identical to the mother plant the seed came from. Therefore, high quality avocado plants are produced by vegetative propagation.

Cuttings and layering are difficult and often have poor results. Budding and grafting are the best methods. Most common are side wedge grafts and shield or chip budding.

Seeds are used for propagation of rootstock (the seed is planted broad-end down). Germination and early growth are rapid. Grafting is usually done when seedlings are about 2 ft tall.

Cultural Practices

Selection of cultivars may be critical to avocado fruit production. Flowers of each particular variety have two distinct periods of opening:

Class A: New flowers open in morning with functional pistils but no shedding of pollen. Flowers close at noon. The same flowers open the next day in the afternoon and shed pollen while the stigmas are no longer receptive. *Hass* is a class A cultivar.

Class B: New flowers open first in the afternoon with functional pistils but do not shed pollen, and close in the evening. The same flowers reopen the next morning and shed pollen. *Itzamna, Fuerte,* and *Linda* are class B cultivars.

Cross pollination is required to set fruit. The primary agents of pollination are honeybees. For effective cross pollination both classes must grow near each other. If your avocado tree flowers but fails to bear fruit, this may be the problem.

Planting distances depend on cultivar, soil type, and topography. Trees tend to grow larger in areas with more rainfall and higher humidity. Closer spacing requires more attention to pruning. Spacing is usually 25 to 35 feet between trees and between rows.

A suggested schedule for using a 10-10-10 fertilizer on transplants is:

Planting time	1-2 ounces
4 months later	2-4 ounces
8 months later	4-6 ounces
12 months later	6-8 ounces

During the second year apply 2 lbs. divided into three or four applications. After the second year, the rule of thumb is about a pound of fertilizer for each inch diameter of trunk. Avocados tend to exhibit a biennial bearing habit (heavy fruiting one year followed by little or no fruit the next year). A heavy crop will require more fertilizer.

Soil pH is very important. Zinc, manganese, and iron deficiencies are more frequent in calcareous soils with pH over 7.

Grafted trees usually bear fruit within three to six years. Earlier fruiting can be induced by girdling. This practice may be most effective at the end of the Summer season. It can be used on trees three or more years after planting. Make a 2 inch wide girdle on one of the main branches. Never girdle the main trunk

Prune only internal branches and dead twigs Heavy pruning is generally not practiced, except to reduce the size of a large tree after many years of growth.

Pests and Diseases

Scale, thrips, and rose beetles are all insect pests of avocado.

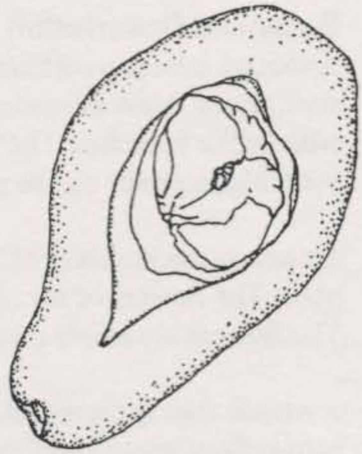
Scale - Natural predators usually keep scale under control. A Volck oil spray may be used if needed.

Thrips - These pests may damage fruit and require a chemical control. See an extension agent or farm advisor for recommendations.

Rose Beetles - May cause serious damage to leaves of young trees. Rose beetles are difficult to control. Request help from an extension agent.

The most important disease of avocado is root rot. Root rot is caused by a combination of *Phytophthora cinnamomi* and poor soil drainage. Using resistant rootstocks and good sanitation are the best preventative practices.

Sunscald is a non-pathogenic disease caused by exposure of immature fruits to intense sunlight. It is more likely to occur on unhealthy trees without enough leaves to shade the fruits.



Avocado branches can also be damaged by sunscald which causes death of the cambium followed by peeling of the bark and possible entry of decay into the branch. This type of sunscald is most likely to occur after heavy pruning.

Weed control is important in young orchards. A thick mulch controls weeds, maintains soil moisture, and protects the delicate feeding roots from excessive heat. Mature trees will shade much of the orchard and reduce weeds.

Harvesting and Storage

Avocados are picked when mature then allowed to ripen off of the tree. A sign of maturity depends on cultivar; green shiny fruits become dull, other types begin to change to a darker color.

References:

Mortenson, E.; Bullard, E.T. 1970. Handbook of Tropical and Subtropical Horticulture. Washington D.C.: U.S. Government Printing Office.

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Yee, W. Date unknown. Producing Avocado in Hawaii. Honolulu: University of Hawaii, CTAHR

Crop Production Report: Mango

Scientific Classification

Family: Anacardiaceae
Scientific Name: Mangifera indica

There are about 400 species among 60 genera in the Anacardiaceae family. Most are tropical trees and shrubs. The genus Magnifera contains 62 species of tall evergreen trees. Of these, 15 produce edible fruit. Mango, M. indica, is the only one widely planted throughout the tropics. Anacardium occidentale, the cashew tree, is another popular crop in this family which is grown for its nuts and fruits.

Botanical Description

Mango is a large, long lived evergreen tree of subtropical and tropical areas. It can live for more than 100 years and grow to 120 feet tall, forming a dense dome shaped canopy. Mango trees have a long, deep tap root with a fibrous system of surface feeding roots. As many as 3,000 flowers develop on the inflorescence that forms on new growth at branch terminals. Male and hermaphrodite flowers are often found on the same inflorescence. Pollination by insects is critical for fruiting. Most trees are self-compatible, so pollination and fertilization within the same tree is possible. The fruit is a fleshy drupe that is extremely variable as to shape, size, color, flavor and other eating qualities; dependent on cultivar.

History/Origin

Mango probably originated as a wild tree in the forests of India. It has been in cultivation for over 4,000 years. From 500 B.C. to 900 A.D., the people of India and Persia spread the crop across Southeast Asia and Africa. In the 18th century it was brought to the New World by Spanish and Portuguese explorers. Mango was introduced into Hawaii from Mexico by a Spanish horticulturist between 1800 and 1820. The Pirie cultivar was brought to Hawaii in 1899. The Haden mango was imported from Florida about 1930.

Local Cultivars

Mango has been naturalized in all the Pacific islands. Mango trees are grown around many homes and also found in the wild. Most of these trees are of seedling origin and produce fruits that are 'common' mangoes for the area. Little crop improvement has been done except for selections from existing populations.

These selections; based on size, flavor, and other eating qualities can then be propagated vegetatively. Many cultivars have been introduced through Hawaii, with Haden and Pirie being the most widely grown.

Haden produces a fruit weighing 1 to 1.5lbs., with some fibers and a small seed. It turns a bright red with some yellow coloring when ripe.

Pirie is a smaller fruit of about 0.5lb. It is fiberless and sweeter than Haden. The skin is greenish-yellow with a slight red tinge when ripe.

Many other cultivars are available. Some to consider for planting are Kent, Rapoza, Carrie, Carabao, and Eduards. Contact an agricultural extension agent for availability and recommendations.

Uses

Mango fruits are most often eaten fresh and fully ripened. They can also be dried or made into juice, jelly and jam. Unripe fruits can be pickled. The hardwood is used for crafts and timber.

Environmental Requirements

Mangoes trees are most productive in hot and dry locations on well drained soils. Low rainfall is preferred because the water supply can be controlled by irrigation, thus reducing rain related problems of disease and poor pollination. An area that is free from strong wind will also improve pollination and production.

In the tropics, mangoes grow from sea level to 4,000 ft., although they do best below 2,000 ft.. Subtropical areas may be limited to lower elevations.

Annual rainfall of 10-100 inches is optimal, with a dry season matched to the flowering and fruiting period. In year-round rainy conditions, damaged flowers and fruit reduce production.

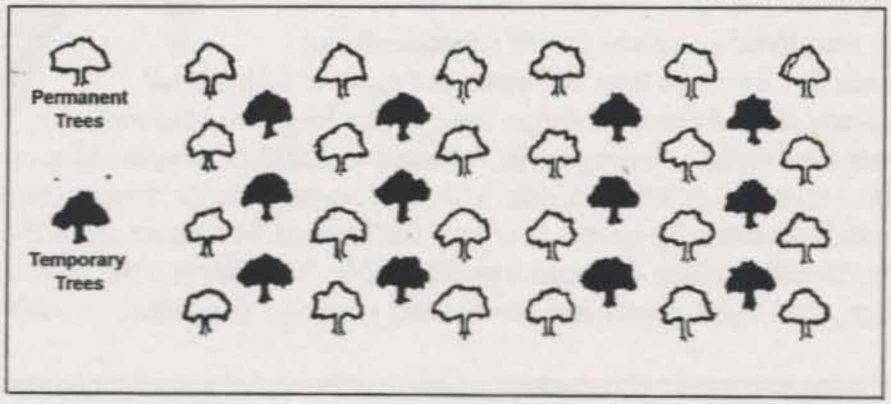
The trees are tolerant of many soil types, but roots can not stay wet for long periods. Very fertile soils may produce strong vegetative growth with limited fruit production,

Propagation and Care

Most mangoes in the Pacific islands have been grown from seed. However, there are two main reasons to change this practice. Trees grown from seeds may produce an entirely different fruit than the parent plant. Although some cultivars, such as Caribao, do breed true they will take many years to reach fruit bearing age.

Vegetative propagation is the best way to produce new plants of selected mango cultivars. Grafting is a preferred method. The cleft graft and side veneer graft are commonly used.

Rootstocks are grown from seeds chosen from vigorous cultivars. Selecting the best scion wood is very important. The best material comes from branch terminals with well developed buds that are swollen and ready to initiate growth. The scion should always have at least one leaf after grafting is completed or else the new plant will die.



Grafted trees that have produced new mature leaves may be planted at any time of the year. Holes should be dug 2-3 feet wide and deep, then partially filled with compost or well rotted manure. The soil should be completely wet before transplanting so the roots do not dry out. If it is a dry time of year, irrigation should be provided until the tree is well established in its permanent location.

Mango trees are usually planted 35 to 40 feet apart in a square pattern. An additional tree may be planted in the middle of each square to increase production for the first 15 to 20 years. At that time the temporary trees are removed.

Young trees should be trained to obtain a good shape. All branches below 2 feet are removed at the trunk. 3 to 4 branches above this are allowed to grow at different heights to form a strong framework. Little more pruning is needed except for the removal of dead branches. Pruning is done when trees are at rest, between the flushes of growth that occur several times a year.

Grafted mango trees usually produce a few flowers by the fourth year, these should be removed to allow the tree to mature. Fruiting will gradually increase so that by the tenth year trees may bear 400-600 fruits. Yield increases until the 20th year then begins to decline at 40.

Mangoes have a habit of only bearing every second year. They may produce a good crop once in a 3-4 year period. The cultivar, soil fertility, heavy rain and wind also affect this condition.

Pests and Diseases

There are many pests of mangoes. Fruit flies are a major problem because the adults lay eggs in mature fruits. Larvae hatch and feed on the fruit making them unusable. The fruit piercing moth is also a problem in some locations. Mango weevils live inside seeds and damage them. Mango vegetation is also attacked by mites, mealy bugs, red banded thrips, scales and other insects.

In many cases biological controls exist to keep these pests in check. When chemical controls are needed consult your agricultural extension office. Do not transport fruit or plant materials outside of quarantine areas.

Anthracnose is the most serious disease of mango. It causes flowers and fruits to turn black and drop off. In high rainfall areas only resistant varieties are recommended.

Sooty mold is a fungus disease that can be controlled by eliminating scale insects problems.

Harvest and Storage

For home consumption fruits are best picked when almost ripe before falling. For longer storage fruits will ripen if picked when full size but not softening. Fruits can be stored from 2 to 4 weeks at temperatures of 45-50 degrees Farenheit.

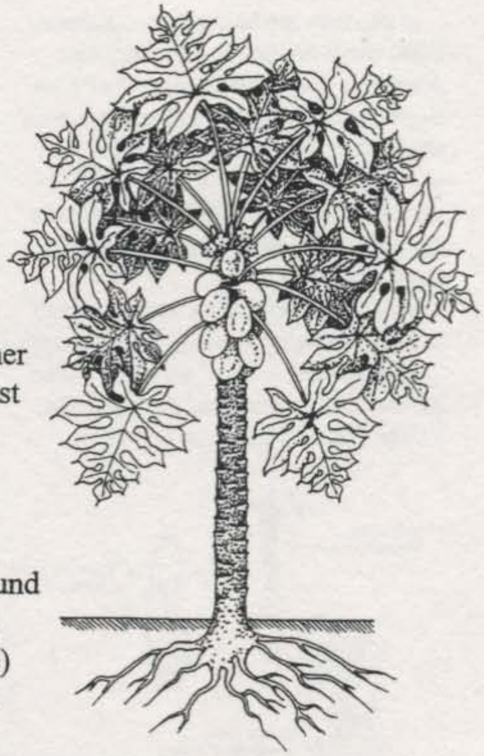
References

Hartmann, H.T.; Kofranek, A.M.; Rubatzky, V.E.; and Flocker, W.J. 1988. Plant Science, 2nd ed. USA: Prentice Hall.

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Yee, W. Date unknown. The Mango in Hawaii. Honolulu: University of Hawaii, CTAHR

Crop Production Report: Papaya



Scientific Classification
Family: Caricaceae
Scientific Name: Carica papaya

Carica papaya is the only tropical crop plant in the Caricaceae family. There are about forty species of plants in the genus Carica, most of which are found in tropical and subtropical America. Another wild species of Carica is harvested in the Andes mountains, and must be cooked before eating.

Botanical Description
The papaya is a soft wooded tree, usually unbranched. The stem is cylindrical and hollow, with prominent leaf scars. The leaves are found at the top of the trunk, arranged spirally on long petioles. Staminate (male) flowers hang off the stem on long panicles. Pistillate (female) flowers are located on short stalks attached singularly close to stem.

Botanically, papaya are very interesting fruits because they are normally Dioecious—having male flowers on one plant and female on another. This means that only the female trees bear fruit. However, hermaphroditic plants are very common among papayas. Hermaphroditic plants have both male and female flowers on the same plant; their seeds result in offspring that are either hermaphrodite or female in a ratio of 2:1. The papaya fruit is a fleshy, smooth berry with a mild pleasant flavor.

History/Origin

The papaya has never been found as a true wild plant. It probably originated in the Mexico/Central America region. Papaya was carried to the West Indies where the Spaniards brought it to the Philippines, and on to India and Africa.

Local Cultivars

Most local cultivars are not actually named, but many growers will tell you their fruits are "round or long, and have red, orange, or yellow flesh."

Fruits can be different shape, size or color depending on the cultivar and sex of the plant. Fruits weighing from 1 to 19 pounds have been reported. Average size fruits can have anywhere from several hundred to a thousand seeds, although seedless fruit sometime occur.

The fruits of female plants are normally round shaped. The fruits of hermaphrodite plants are normally larger and longer, and have notable grooves that run the length of the fruit.

Because sex is determined by genetics some cultivars have been developed that are usually hermaphroditic. A hermaphrodite plant is the best choice for growers because it will pollinate itself and bear fruit regularly. Some examples include Solo from Hawaii, or Sunnybank from Australia.

Uses

Papaya is commonly grown for its ripe fruit, which is eaten fresh, made into juice, jam, ice cream flavoring, or canned in syrup. It is rich in vitamin A and vitamin C. The unripe fruits are used in some places for cold salad or relish and pickles.

A very different product is harvested from the unripe fruit while it is still on the tree. This material comes from the latex which can be taken by cutting the immature fruit. The latex contains an enzyme called papain that is used to make meat and other foods tender. It is also used in the processing of cloth materials.

Environmental Requirements

The plant is a tropical perennial which can be grown within 32 degrees north or south of the equator and up to 5000 feet of elevation in these areas.

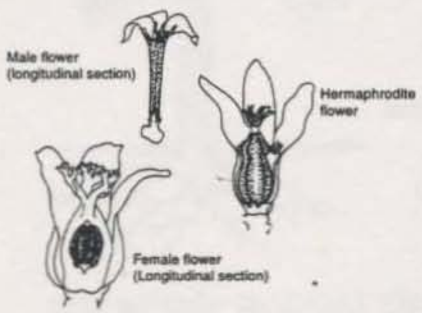
It does best in full sun with well drained, fertile soil and will not grow in extremely wet areas.

Propagation

Papaya plants are usually grown from seed. Seeds should germinate in 10-14 days. Seedlings may be started in boxes or peat pots. Three to four weeks after germination, seedlings are moved to poly bags. Care must be taken to not damage the roots. After another two months (8 to 10 weeks after seeding) they are ready for transplanting into the field. Three plants are placed at each location until their sex can be determined.

If papayas are being direct planted, 6000 seeds are needed to plant one acre with five to seven seeds per hole. Seedlings are thinned to three per hole until sex is declared at flowering, in about six months. At that time all seedlings are removed but one female per hole. One male plant is grown for every 25-100 females.

If the hermaphrodite varieties such as Solo are being grown, one hermaphrodite per hole is kept, all other plants are commonly removed so that fruits will be uniform in shape and size.



Cultural Practices

The usual crop spacing for papayas is 8 to 12 feet apart between and in the rows. After transplanting, water and shade may be needed until plants are well established. Ring weeding is required around plants, and mulch will help control weeds and conserve moisture.

In Hawaii, 3 lbs. of compost and 1-2 lbs. of triple superphosphate are recommended in the planting hole. 1/4 lb. of complete fertilizer is applied monthly till flowering and 3/4 lbs. every 2 months thereafter. Fertilizer is applied around the plants drip line area.

Trees begin to bear fruit 8 to 12 months after being planted. Although the trees may live for 25 years, most are chopped down after three or four years because they are too tall to harvest easily. Trees grow up to 30 feet tall, but can be forced to branch by cutting back or injuring the apical meristem.

Pests and Diseases

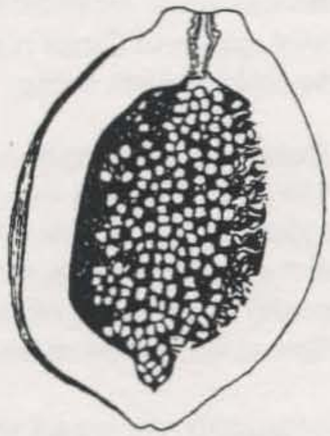
Mites, aphids and thrips are the most common pests of papaya. In most cases they cause minor leaf damage and are kept in check by natural predators. Wettable sulphur, insecticidal soap, or mild pesticides may be used if needed. Consult your local ag. extension office.

In Hawaii the major insect problem is the Mediterranean Fruit Fly, which currently prevents export of papaya to the U.S. mainland and Japan.The opportunity for an export market may exist in areas that do not have this pest.

A substantial number of diseases affect papaya production in the Pacific islands. Anthracnose, phytophthora (foot rot), stem end rot and black spot are fungal diseases. Powdery mildew is another common problem. These are all most evident during the rainy season. Local agriculture extensionists can provide specific recommendations.

Papaya Ring Spot Virus is a very serious disease affecting this crop industry in Hawaii. It was previously called Papaya Leaf Mosaic because a yellow pattern on the leaves is the first symptom. Later symptoms are malformed leaves and petioles, circular green spots on fruit, misshapen fruits, and eventually death of the plant.

This disease is spread from plant to plant by aphids. New plants can also be infected by contact with people or tools that have touched diseased plants. The only control at this time is to destroy infected plants. Cucurbit plants such as pumpkin, cucumber and melons may also harbor the disease.



Harvesting and Storage

Papaya fruit can be harvested as soon as color begins to change; ripening will continue after harvest. Early harvesting often occurs to allow more time for shipping and a longer shelf life. It also limits bird and insect damage. For home consumption, fruits may be sweeter if left on the plant until fully ripe.

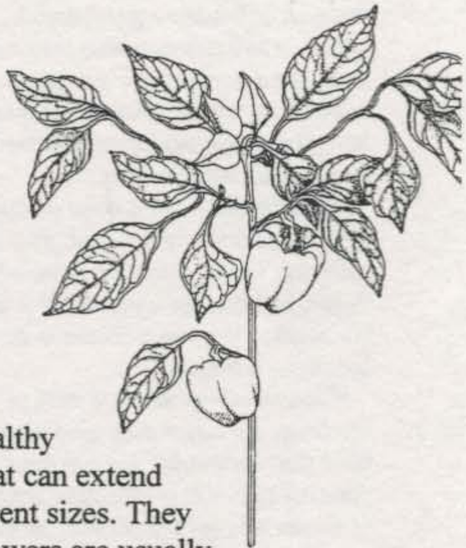
References

Barden, J.A.; Halfacre, R.G.; and Parrish, J.D. 1987. Plant Science. New York: Mcgraw Hill Book Company.

Mortenson, E.; Bullard, E.T. 1970. Handbook of Tropical and Subtropical Horticulture. Washington D.C.: U.S. Government Printing Office.

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Crop Production Report: Bell Pepper



Scientific Classification

Family: Solanaceae
Scientific Name: Capsicum annum

Classification is rather confucing because there are over 100 species in the genus and many cultivars within some species. Bell peppers are closely related to the hot peppers, Capsicum frutesens. Bell peppers should not be confused with white or black pepper, Piper nigrum.

Botanical Description

Bell peppers are herbs, but may sometimes be woody at their base. A healthy plant can grow between two and five feet tall, and has many branches, that can extend out to about three feet from the stem. The simple leaves have many different sizes. They may be broadly lanceolate to ovate and entire, with an acuminate tip. Flowers are usually borne singly at the ends of branches. Fruits are many-seeded berries, which hang from the branches. Fruits are variable in size, shape, color and degree of pungency, depending on the cultivar.

History/Origin

Capsicum peppers probably originated in South and Central America. It is reported that Columbus introduced the fruits to Spain following his trip to the New World. The seeds' lengthy viability and small size were factors that helped their quick distribution throughout the world.

Local Cultivars

The best way to determine cultivars suited for a certain location is by variety trials. Trials should include the varieties Yolo Wonder, Keystone, and Florida Giant since they are resistant to Leaf Mosaic virus.

Uses

The bell pepper is usually used for flavoring in salads, stir fry, and other dishes. It is eaten raw or cooked.

Bell peppers are considered difficult to produce and are not widely grown in the Pacific islands. This makes it a high value crop for successful growers.

Environmental Requirements

In the tropics and sub-tropics, bell pepper require moderate temperatures to grow well. If the temperature is higher than 75°F, fruit set is poor and sunburning may occur. This means it is best grown in the winter or at higher elevations.

The soil should be fertile and well drained with a good moisture holding capacity. Saturated soil can cause the plants to drop their leaves.The use of manure or compost is recommended to improve soil conditions and increase organic matter content.

Bell peppers are not very drought tolerant.Heavy rainfall is not good either, since it damages flowers leading to a poor pollination and fruit set.

Propagation

Bell pepper seeds are small. They germinate in 8-10 days. Seedlings are slow growing at first. They are usually started in flats or containers then transplanted to the field. This increases seedling survival and gives seedlings a head start on weeds.

Cultural Practices

Seedlings are usually transplanted to the field when they are four to five weeks old, or four to eight inches tall. Plants should be exposed to increased amounts of sun and wind a week or two before transplanting to "harden" them. The lowest leaves should be trimmed off to reduce water loss.

Transplanting late in the afternoon rather than in the morning gives the plants a chance to partially recover from the shock of being transplanted before being exposed to the full heat of the day.

Plants are usually planted in rows three to four feet apart, with 1 to 1.5 feet between plants within rows. If set deeper in soil than in the container, roots will form on the buried portion of the stem. Give the new plants water immediately after transplanting.

Split application of small amounts of fertilizer will provide nutrients as needed. Fertilizer should not be too high in nitrogen or plants will be very succulent and susceptible to insect and disease damage. High nitrogen will also delay fruit set.

Use a complete fertilizer such as 10-10-10 at planting time. A 10-20-10 mix is best at flowering, and again at fruiting to prevent a setback in growth. Some farmers prune plants and side dress again following harvest. This may result in a good second harvest.

Weeds, Pests & Diseases

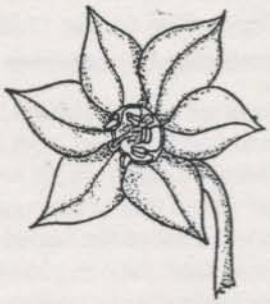
Weeds can cause serious losses because bell peppers are generally not very vigorous plants and do not have an extensive root system. Good weed control is essential for high production. Some useful weed control techniques include:

•Stale seed bed - cultivate and irrigate the plant area one to two weeks prior to transplanting and allow weeds to germinate. Cultivate again just prior to transplanting to kill the germinated weeds.

•Mulching - Any type of organic material will make a good mulch, maintain soil moisture and keep soil from getting too hot as well as controlling weeds. Mulch is generally less effective against purple nutsedge than against other weeds.

•Solarization - use a clear plastic mulch on bare irrigated soil prior to planting. To be effective, solarization should be done for a period of four to six weeks. It is most effective during hot sunny weather.

•Late planting - waiting until pepper seedlings are larger may give them a head start on weeds. Do not delay planting after soil preparation however, or weeds will get a head start on your pepper plants.



Pests and Diseases

Bell peppers are subject to attack by several insects, but the most common are aphids and mites.

Aphids are small green or yellowish-green insects, often present in great numbers on young leaves and flowers. Aphids damage plants by sucking plant sap. They often cause distortion and downward curling of leaves. Aphids can often be controlled by homemade soap or garlic sprays.

Mites are tiny animals closely related to spiders. Mites suck plant sap from under the young leaves, causing distortion and mottling on the upper leaf surface. Controlling mites is often more difficult than controlling aphids. See an extension agent for pesticides recommendations.

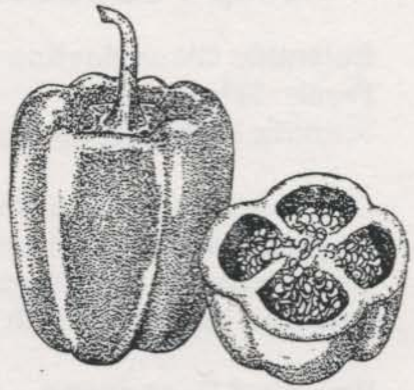
Nematodes are tiny worms that feed on the roots. Symptoms are wilting during the day and recovering at night. Root knot nematodes cause swellings on the roots. Use bell pepper varieties that are resistant to nematodes.

Peppers are subject to many diseases. Among the worst are:

Bacterial wilt, which is caused by a bacteria, *Pseudomonas solanacearum*. This disease affects tomatoes and eggplant as well. It causes wilting and death of the entire plant. The first symptoms are wilting of the young leaves. The entire plant often wilts in a few days after the first symptoms.

Bacterial wilt can often be identified by cutting the lower stem to look for a dark ring inside. Bacterial wilt can survive in the soil for up to five years. Many farmers have had to give up growing solanaceous crops after accidentally introducing this disease to their farms. There is no good control for this disease except prevention. Be careful not to introduce potentially infected plants into your field.

Leaf Mosaic is caused by a virus. The symptoms are distinct mottling and distortion of the leaves. People often mistake mite damage for mosaic. It is highly contagious and is easily spread by contact with infected plants, or by people who have handled infected plants. It is also transmitted by insects.



Sunscald occurs when the foliage of the plants is not dense enough, and fruits are scalded by the sun. This results in dead spots on the shoulders of the fruits, which can then begin to rot and cause the entire fruit to decay. Even when the entire fruit is not destroyed, its market value is greatly reduced. Good soil fertility and insect and disease prevention will help plants produce adequate foliage to prevent sunscald.

Harvesting and Storage

Bell peppers should be harvested when mature green. The skin of mature green peppers is shiny and waxy while that of the immature pepper is not. Peppers harvested too young will wilt and shrivel. Stems should be left on the fruits when they are harvested.

Because bell peppers are delicate, they should be handled gently.

The fruits should be taken to market as quickly as possible. Keep cool and shaded following harvest. Do not freeze.

References

Hartmann, H.T., A.M. Kofranek, V.E. Rubatzky, W.J. Flocker. 1988. Plant Science. 2nd ed. USA: Prentice Hall.

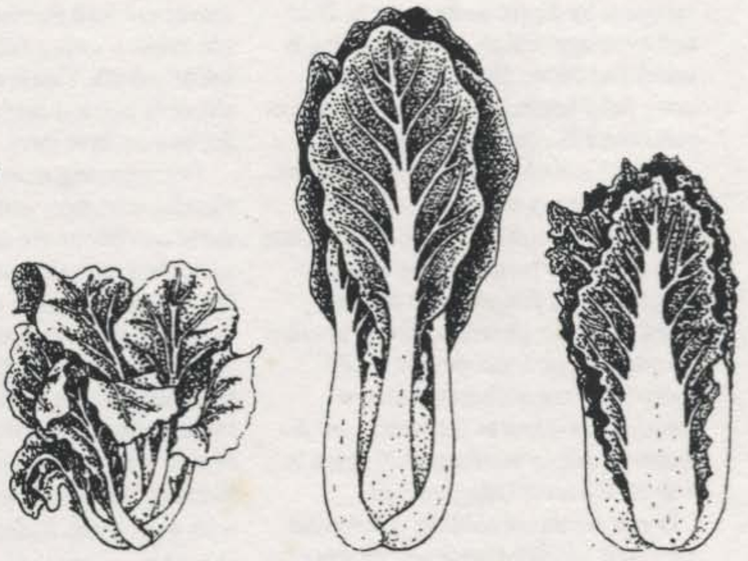
Lee, C.-T.. 1981. Growing Bell Pepper in Guam. Guam: University of Guam, CALS.

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Crop Production Report: Chinese Cabbage

Scientific Classification

Family: Cruciferae
Scientific Name: Brassica campestris



There are nearly 3,000 species in the Cruciferae family, most of which are herbaceous and more well suited to temperate climates. Some other well known "Crucifer" crops include; head cabbage, radishes, broccoli, turnips,cauliflower and brussel sprouts. As a result of breeding and selection many of these have cultivars that can be grown in the tropics even at lower altitudes.

Botanical Description

Chinese cabbage is a biennial herb grown as an annual. Leaves grow in a rosette pattern close to the ground with no branching or internodes. Leaves are 6 to 18 inches long, varying from cream color, to pale or dark green. Petioles are wide, fleshy, white or green. Roots are fibrous. Flowers are yellow and about a 1/2 inch long. There is sufficient variation in the campestris species due to natural crossings and human selection to have resulted in two subspecies (ssp.)

- The subspecies chinensis is the non-heading type. Cultivars within this group are characterized by dark green leaves and thick white petioles.
- The subspecies pekinensis is the heading type. Cultivars within this group are compact to slightly compact with thin leaves of pale green to cream color. Petioles are fleshy but more flexible than those of most chinensis cultivars.

History/Origin

Chinese cabbage is believed to have originated in China where it has been cultivated for almost 1,500 years. It was probablyintroduced into the Pacific by Chinese and Japanese emigrants in the early 1900's. It is a popular leaf crop in Pacific islands and much easier to grow than salad lettuce in tropical conditions.

Local Cultivars

There are considerable differences amongst the cultivated varities that are grouped into a subspecies by their heading and non-heading qualities. Common and scientific names amongst these cultivars are often confused.

The nonheading chinensis ssp. contains three common cultivars. Bok Choy, has smallish shiny dark green basal leaves with large white petioles. Pak Choi is similar however the dark green leaves are larger. Mustard Cabbage has a paler green leaf with thinner more pliable petioles.

Pekinensis, the heading ssp., also has three commonly cultivated varieties. The two types of Won Bok are characterized by compact heads and leaves with a fleshy white central vein. One has pale green and round leaves, and the other has lacy leaves with a cylindrical shape.

'Saladeer' is the commercial name of a pekinensis cultivar that has a slightly compact head with light green colored leaves and white or green petioles. The leaves of 'Saladeer' are thin and succulent for use in salads. It is well suited to the tropics because of its early maturity, ability to grow in high temperature /moisture conditions, and resistance to disease by comparison to lettuce.

Uses

All of the cultivars can be used in soups and stir fry dishes. Won Bok is eaten cooked, or preserved for dishes such as kim chee. The tender leaves of Saladeer are most often eaten fresh. Like other leafy green vegetables they are all good sources of vitamins (A and C) and minerals (Calcium and Iron).

Environmental Requirements

Chinese cabbage can be grown on a variety of soil types. However, because it is very leafy with short fibrous roots it has a tendency to wilt when grown in sandy soils. Organic matter in the soil is helpful for holding moisture at the surface. Daily rainfall or available irrigation are critical during sunny, hot or windy conditions.

Propagation

There are two ways to start Chinese cabbage; by direct seeding in the field and by transplanting. Direct seeding is easier and faster. However, it is also more risky because the sun, hard rain, or pests can kill unprotected seedlings.

In both methods you need to prepare the soil. It is not necessary to plow or turn over the land but soil in the planting area should be level, broken into fine particles, well drained, and free of weeds. Using a shovel or trowel prepare the soil at least 4 inches deep. Add compost mixed with a teaspoon of complete fertilizer at the bottom of the prepared soil so seedlings will reach it without the roots being burned.

If you are direct seeding you should put about 1 inch of fresh soil on top of the mixed soil and pat it down. Onto this four or five seeds are placed at each planting site and covered with another half inch of soil.

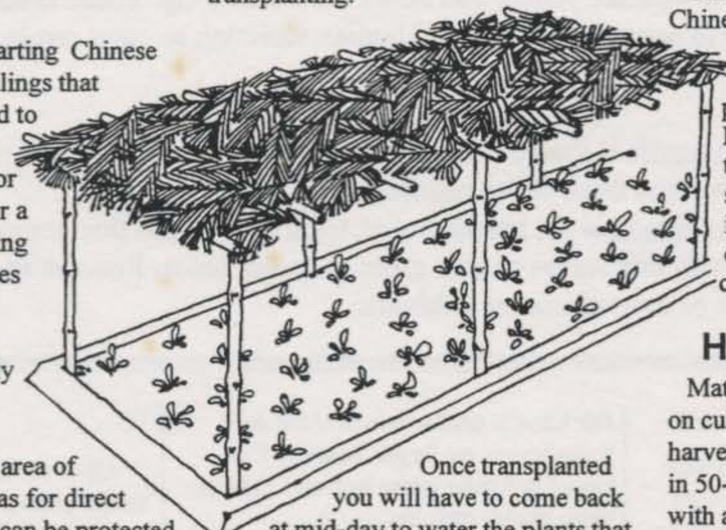
The second way of starting Chinese cabbage is to grow seedlings that will later be transplanted to the field. Seedlings can be grown in small pots or disposable cups, flats, or a prepared seedbed. If using pots or flats, 3 to 4 inches of the soil mixture is placed in the container. Seeds are planted, lightly covered with soil and watered.

A seedbed is a raised area of land with soil prepared as for direct planting. The seedlings can be protected from the sun and rain with a cover of coconut leaves. These leaves are gradually removed to harden the older seedlings. Pests are also more easily controlled in a seedbed as compared to direct seeding to a large field.

In all methods, the seeds usually germinate after 2 or 3 days. It is not necessary to thin them until the first true leaves are well formed. When seedlings are about 3 inches tall they should be hardened off. This is done by removing shade or placing containers in the sun for two or three days.

Transplanting should be done on cloudy, cool days whenever possible. If these conditions are not available, transplant in the late afternoon to allow the plants to become adjusted before exposure to the next day's hot sun.

Plants get most of their water through root hairs. When seedlings are moved in the soil these are easily torn off. It is best to water seedlings thoroughly prior to transplanting and move some soil with each plant. Before this is done you should have dug holes about one foot apart and deep enough so the plant will be level to the surrounding soil after transplanting.



Once transplanted you will have to come back at mid-day to water the plants that have wilted. If watered they will recover quickly. If not watered they will die. This may be needed for the first 7 days after transplanting. Seedlings will show a quick response to applications of weak water soluble fertilizer at this time.

Pests and Diseases

Chinese cabbage is affected by a number of pest and disease problems. Young seedlings are a favorite food of African Tree Snails. These pests will travel a long distance at night to find a seedbed or destroy a newly planted field. Tall weeds around the sides of the field are a common daytime hiding place that should be removed. Snail bait is also a very effective control.

The black flea hopper is an insect that punches many holes in leaves with its mouth. This can severely stunt the growth of young plants. The damage ruins the appearance of mature plants. If this is a serious problem spraying the leaves once or twice may be required. Take care not to kill beneficial organisms such as lizards and toads.

Cabbage loopers and Diamond-back Moth larvae can cause severe damage. *Bacillus thurengensis* may be an effective biological control

The soft fleshy stem and petioles of Chinese cabbage grow close to the ground. This makes it an easy target for soil borne diseases, particularly Rhizocotonia and Bacterial Soft Rot. To control these diseases, Chinese cabbage should not be grown two seasons in a row on the same area of land, or where other Cruciferae family crops have recently been grown.

Harvest and Storage

Maturity and yield varies depending on cultivar. Non-heading types can be harvested in 40-60 days and Won Bok in 50-80 days. Cutting plants at the base with a sharp knife can avoid getting the leaves covered with soil. Damaged leaves should be removed after harvest. Rinse the plants then store them in open plastic bags.Chinese cabbage wilts very quickly, so buyers or consumers should be arranged before harvest.

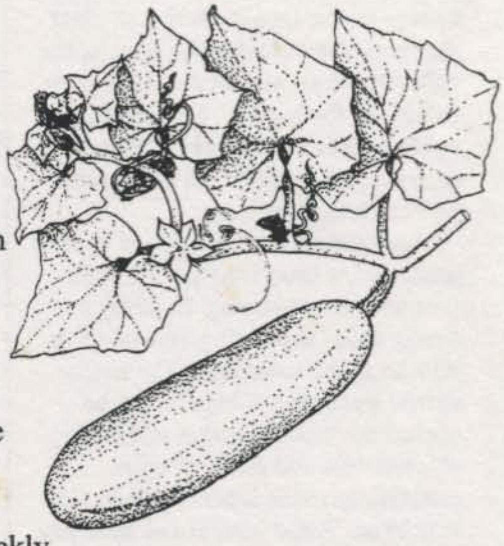
References

Mortenson, E.; Bullard, E.T. 1970. Handbook of Tropical and Subtropical Horticulture. Washington D.C.: U.S. Government Printing Office.

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Wanitprapha, K.; Huggins, C.; and Nakamota, S. 1992. 'Won Bok and Pak Choi-Economic Fact Sheet #18'. Honolulu: University of Hawaii - CTAHR.

Crop Production Report : Cucumbers



Scientific Classification

Family: Cucurbitacae
Scientific Name: Cucumis sativus

The Cucurbitacae family contains 90 genera with 750 species. Amongst these are numerous vegetables and fruits grown in the Pacific islands including; cucumbers, pumpkins, and melons. Each of these species contains many cultivars. Only different cultivars within the same species can interbreed.

Botanical Description

Cucumber seeds usually germinate 7 to 14 days after planting. The seedlings have one strong tap root but the other roots are shallow with fibrous growth. The cotyledons look different from the true hairy leaves. Once the true leaves are produced the vines grow quickly. The plant grows tendrils to hold on for upright support.

After about three weeks of growth, monoecious flowers begin to appear. The first blossoms are male flowers. About one week later female blossoms are produced. Each flower lives only one day. Female flowers have a tiny fruit at the base below the petals. These grow into full sized vegetables once the flower is pollinated. Bees and other large insects are the main pollinators. Once the seeds in the vegetable reach maturity, the plant stops flowering.

History/Origin

Cucumber probabaly originated in Northern India. It is a crop with a long history of cultivation from the time of the Egyptians, Greeks, and Romans; to. currently being grown throughout the world.

Local Cultivars

Cucumbers are very popular crops in the tropics. However, disease problems have been the cause of total crop loss. Field trials with resistant cultivars are used to make appropriate selections.

Field trials in American Samoa have identified the following cultivars; Green Bowl, New Market #2, New Market #3, and Sure Green. Some recommended cultivars in Hawaii include; Supersett, Slicemaster, Genuine, and Sweet Slice. Contact your local agricultural extension office for further information.

Uses

The immature fruits of cucumber are eaten as a fresh salad vegetable. They are also used in soups and other hot dishes. Small, young fruits can be made into pickles or relish. Young leaves and flowers may be blanched for use as salad greens or cooked like spinach.

Environmental Requirements

Cucumbers can grow under most warm weather conditions as long as there is enough water for healthy growth. Ideal temperature for cucumber growth is 85°F during the day and 65-70°F at night. Too much rain may result in disease problems and limit pollination. They are not tolerant of waterlogged conditions and do best in sandy soils with pH of 5.0 -7.0.

Propagation

Cucumbers can only be grown from seed, and the usual method of planting is direct seeding. Young plants do not transplant very well due to their brittle tap roots.

Seeds can be planted in rows or hills, and should be fertilized at planting time. This is done by mixing a complete fertilizer with soil and placing the mixture below or to the side of the seeding location. Manure or compost can also be used in this way.

When row planting, the cucumbers should be planted about eight to 10 inches apart in the row, with four to six feet of space between the rows.

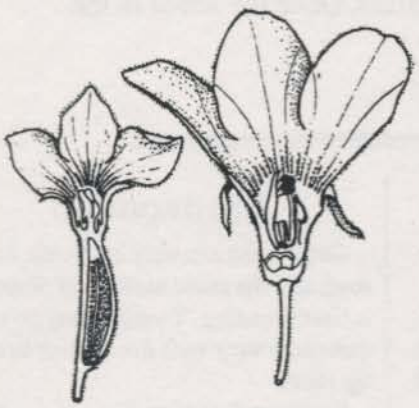
When hill planting, each hill should contain no more than five plants The hills should be five feet apart between rows and hills.

Cultural Practices

Since cucumbers are large vining plants, cultural practices are often used to save space. One method is to plant the cucumbers close to the edge of the cultivated area, and let the vines grow outside of the garden . Use shallow cultivation to control weeds when the crop is young, and mulch the ground before vines grow long.

Vine crops are often trellised to save space and to keep the fruits off the ground to avoid rotting. Building a strong trellis at planting time prevents injuries to the roots later. The trellis should be at least 5' high. It can be made from wooden stakes and netting, chicken wire and posts, or other materials the vine tendrils will be able to hold on. Weed control and mulching are easier under a trellis but still important practices to be completed.

Farmers should pinch the ends off of the vines when they become too long. Removing vine tips also forces energy into fruit production.



The timing of pollination is critical in this monoecious crop since flowers are only open for one day. Hand pollination can be easily done if weather or other factors limit available pollinators. Remove a mature, male flower from the vine and strip it of petals. Insert the stamen into each female flower, using new male flowers as needed.

At planting time, one cup of complete fertilizer is used for each hill or five feet of row. Sidedress lightly when the vines have reached one foot tall. Side dress again when the first fruit begin to grow

Pests and Diseases

There are many pests of cucumbers and other members of the Cucurbitacae family.

Thrips and Aphids are sucking insects. These pests are small but can be seen on the underside of leaves. A few are often present but too many will greatly reduce the vigor of the plant. Symptoms are curled leaves and stunted vines. Plants should be watched for infestation. Check with extension agents for recommended controls.

The Cucumber Beetle, Cucumber Ladybeetle, and Leaf Miner are chewing pests. The first two eat the underside of leaves resulting in scraped patterns of damage. The Leaf Miner tunnels through leaf interiors. If any of these pests become numerous , contact an agricultural extension agent for recommended controls.

Diseases are a chronic problem for cucumber producers in tropical climates.

Anthracnose, Powdery Mildew, and Gummy Stem Blight all favor wet, humid weather. Virus diseases such as Leaf Mosaic are spread by vectors including aphids. Bacterial Wilt is a soil borne disease.

Identifying resistant varieties suited to local conditions is an important preventative practice. Growing the crop at appropriate times of the year will reduce some problems. Monitoring the crop and providing good sanitation are also critical. Fungicides may be a last alternative in some cases. However the waiting period from spray to harvest must be understood and practiced.

Harvest and Storage

Cucumbers are best harvested when full-grown but immature, before many seeds develop. Full maturity of fruit on the vine will trigger senescence in the plant. Plants should be checked at least every second day during fruiting. Cucumbers should be refrigerated if stored for five days or more.

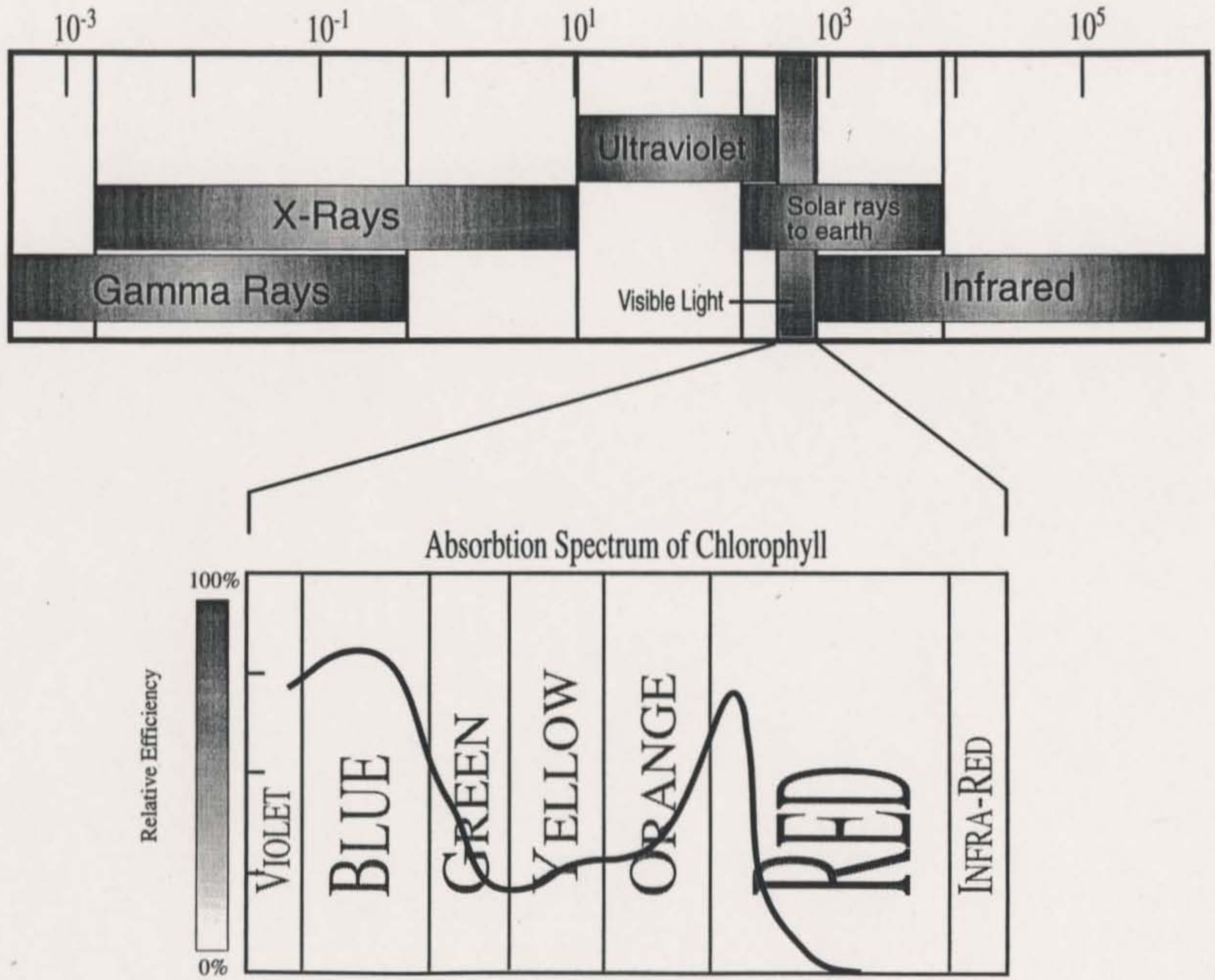
References:

Hartmann, H.T.; Kofranek, A.M.; Rubatzky, V.E.; and Flocker, W.J. 1988. Plant Science, 2nd ed. USA: Prentice Hall.

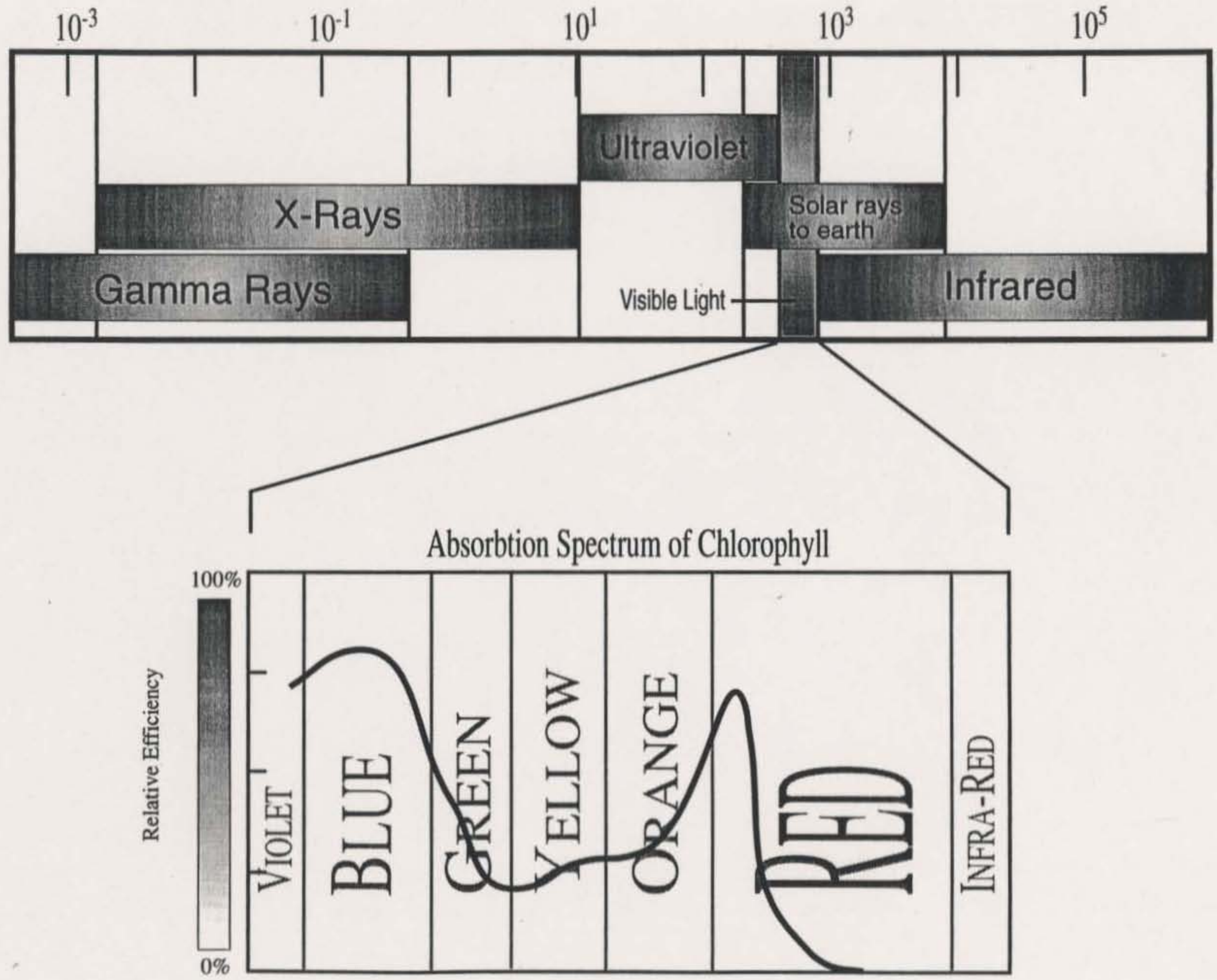
Mortenson, E.; Bullard, E.T. 1970. Handbook of Tropical and Subtropical Horticulture. Washington D.C.: U.S. Government Printing Office.

Purseglove, J.W. 1988. Tropical Dicotyledons. Singapore: Longman Singapore Publishers.

Overhead Transparency Masters



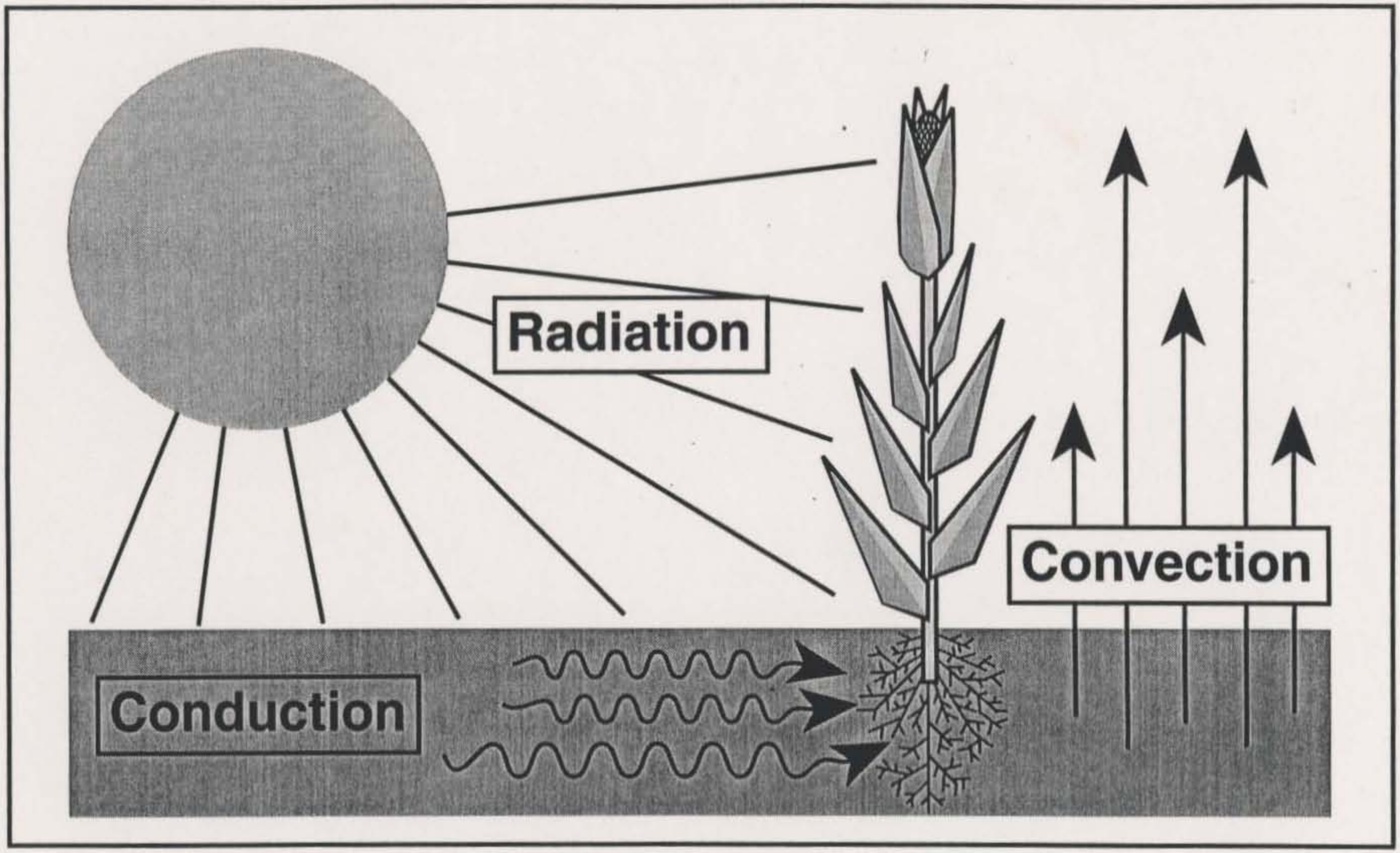
10-3
10-1
10¹
10³
10⁵
Ultraviolet
X-Rays
Solar rays to earth
Gamma Rays
Visible Light
Infrared
Absorbtion Spectrum of Chlorophyll
100%
Relative Efficiency
0%
VIOLET
BLUE
GREEN
YELLOW
ORANGE
RED
INFRA-RED

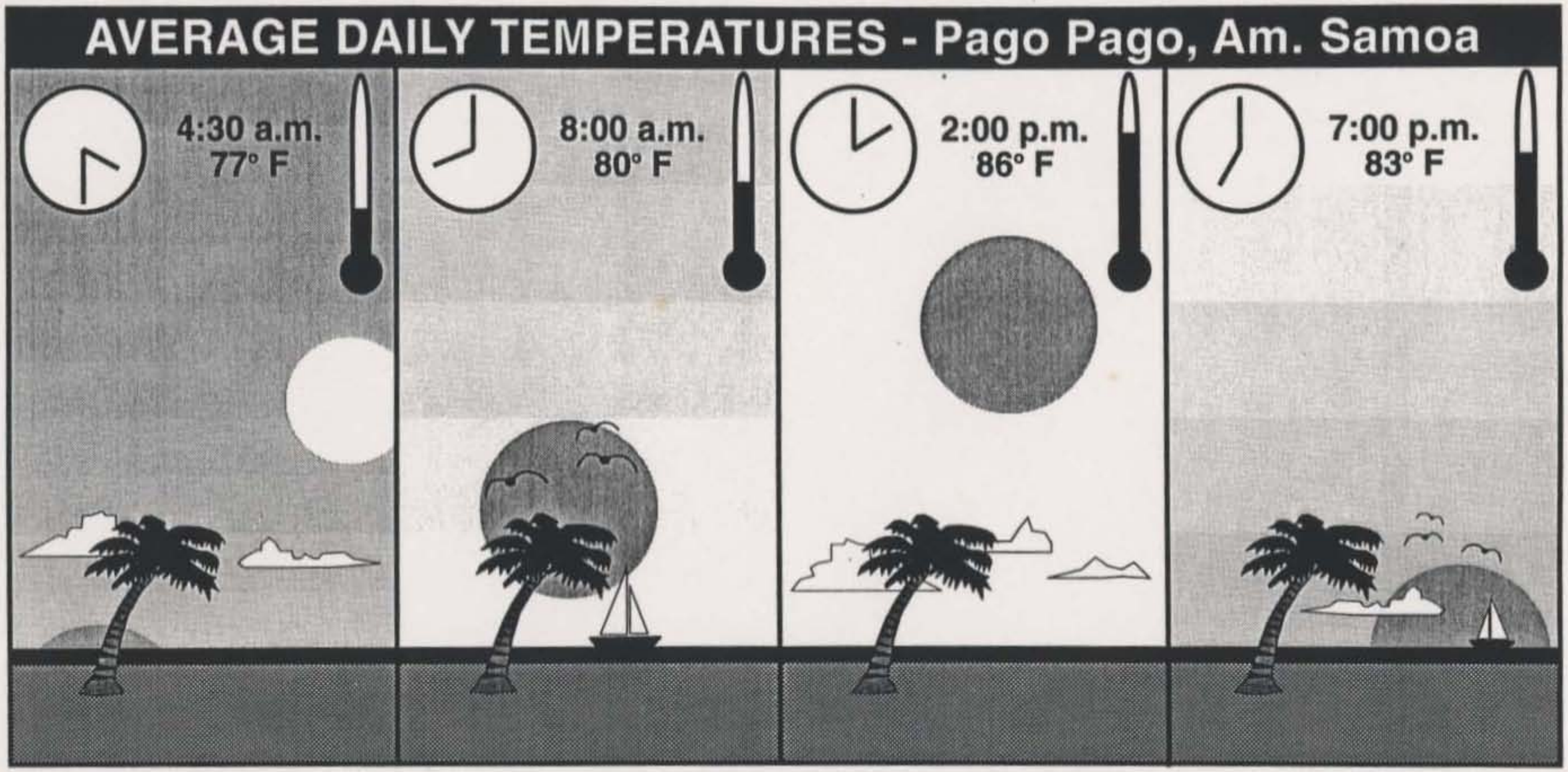


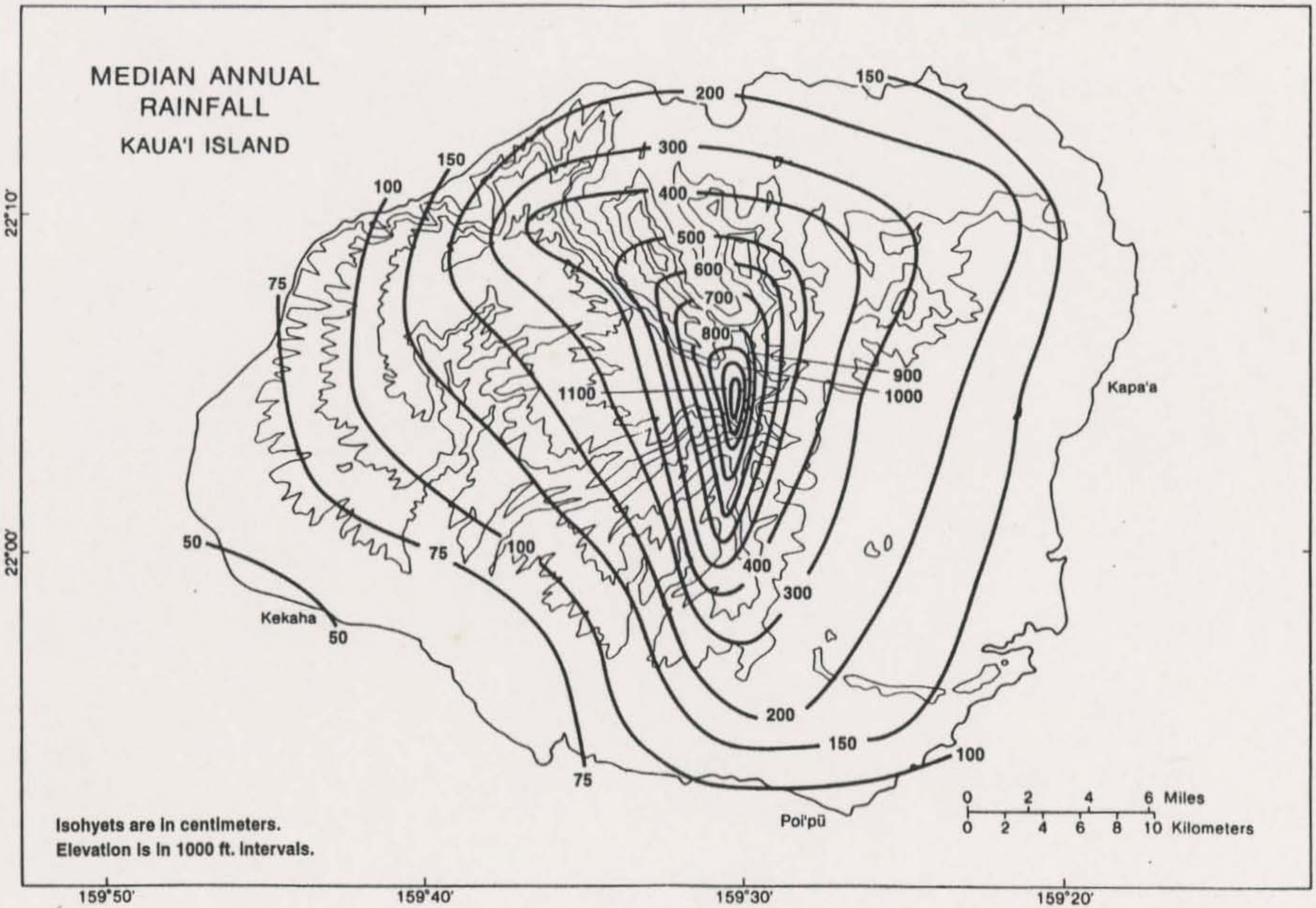
10^{-3}
10^{-1}
10^{1}
10^{3}
10^{5}
Ultraviolet
X-Rays
Solar rays to earth
Gamma Rays
Visible Light
Infrared
Absorbtion Spectrum of Chlorophyll
100%
0%
Relative Efficiency
VIOLET
BLUE
GREEN
YELLOW
ORANGE
RED
INFRA-RED

The Effect of Latitude and Season on Daylength

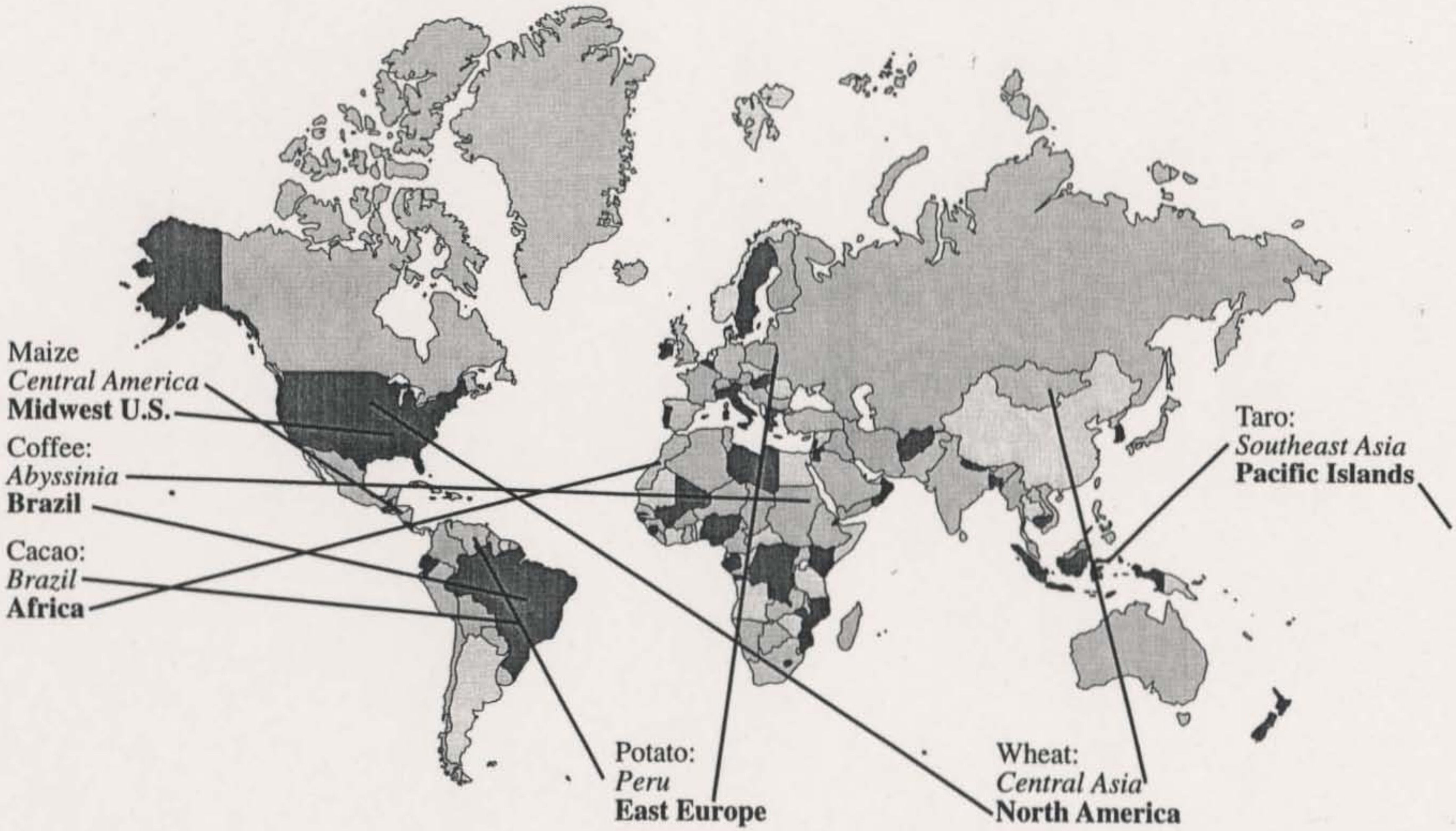
Latitude, °N	*Mar 21*	*June 21*	*Sept 21*	*Dec 21*
0	12 hours	12 hours	12 hours	12 hours
10	12 hours	12 h, 35 min	12 hours	11 h, 25 min
20	12 hours	13 h, 12 min	12 hours	10 h, 48 min
30	12 hours	13 h, 56 min	12 hours	10 h, 4 min
40	12 hours	14 h, 52 min	12 hours	9 h, 8 min
50	12 hours	16 h, 18 min	12 hours	7h, 42 min
60	12 hours	18 h, 27 min	12 hours	5h, 33 min
70	12 hours	Two months	12 hours	No daylight
80	12 hours	Four months	12 hours	No daylight
90	12 hours	Six months	12 hours	No daylight


Radiation
Convection
Conduction


AVERAGE DAILY TEMPERATURES - Pago Pago, Am. Samoa
4:30 a.m.
77° F
8:00 a.m.
80° F
2:00 p.m.
86° F
7:00 p.m.
83° F



MEDIAN ANNUAL
RAINFALL
KAUA'I ISLAND
200
150
300
400
500
600
700
800
900
1000
1100
100
75
50
Kekaha
Kapa'a
Poi'pū
Isohyets are in centimeters.
Elevation is in 1000 ft. intervals.
0 2 4 6 Miles
0 2 4 6 8 10 Kilometers
22°10'
22°00'
159°50'
159°40'
159°30'
159°20'



Center of origin are *italicized*. Centers of modern production are **boldfaced**.

Examples of fertilizer and rice yield data

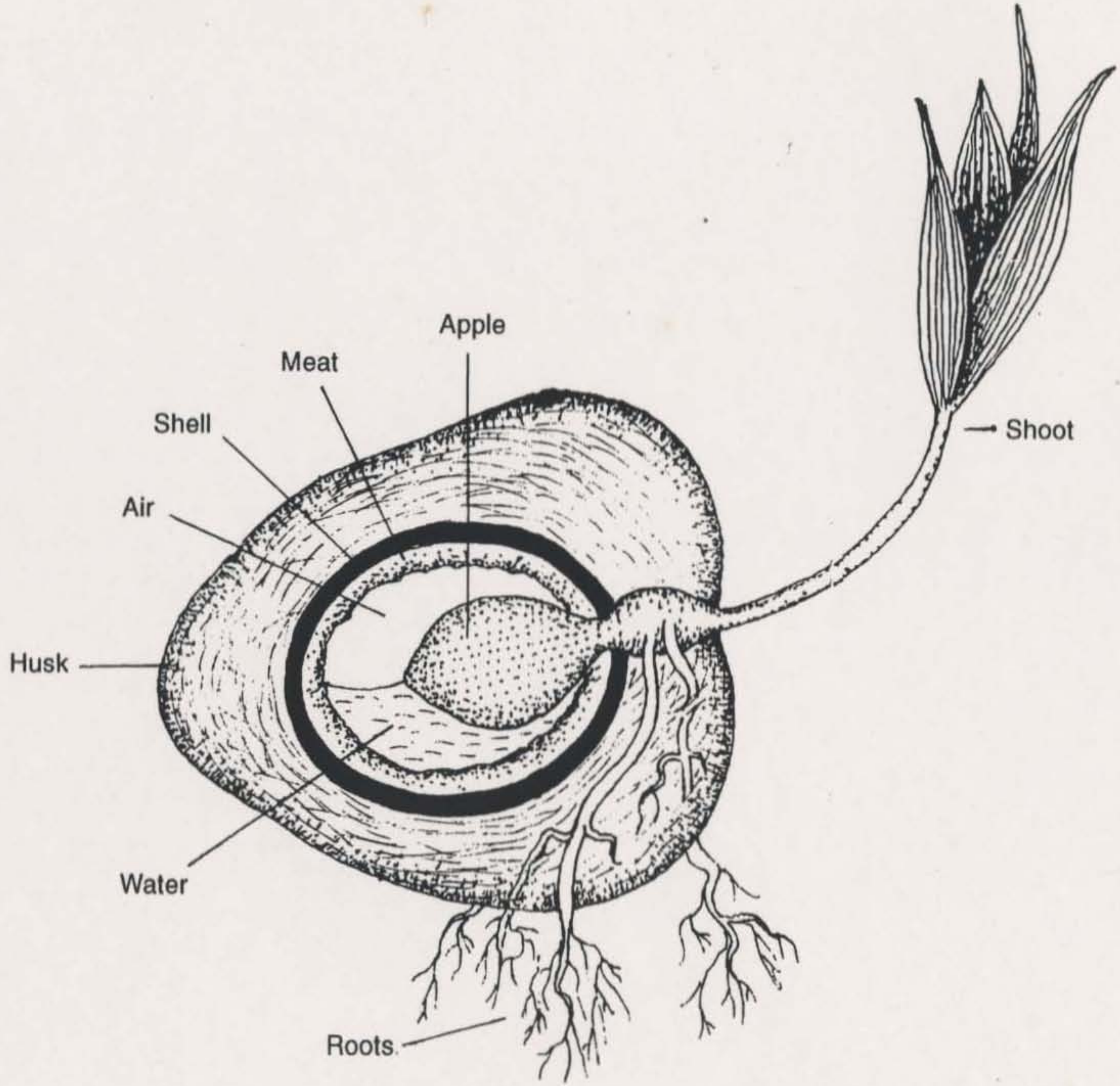
Country	**Fertilizer (kg/ha)**			**Yield (tons/ha)**
Thailand	No fertilizer			1.2
Philippines	5(N)	5(P)	3(K)	1.3
Japan	85(N)	57(P)	62(K)	4.5
U.S.A. (California)	140(N)	50(P)	* (K)	5.5

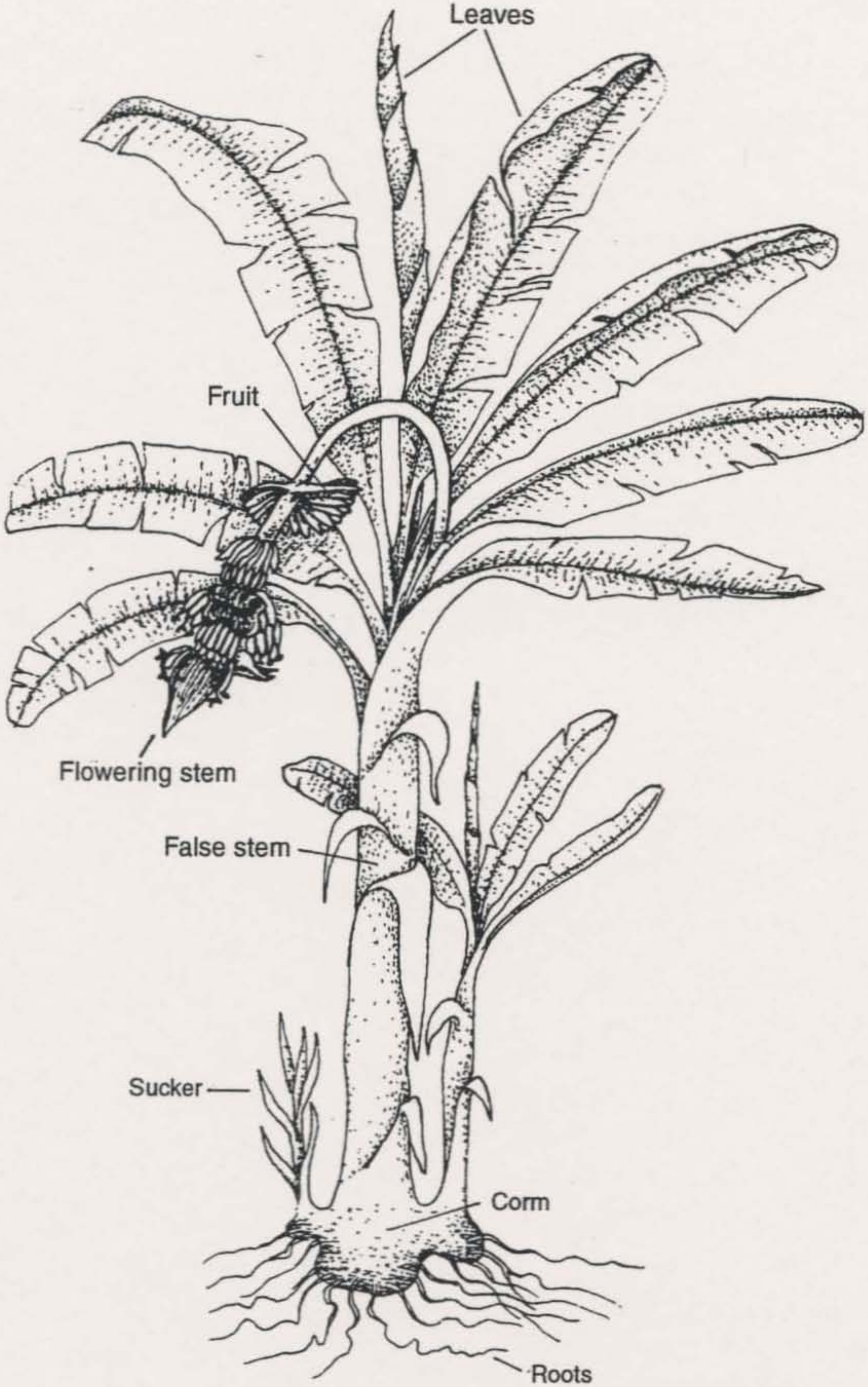
* based upon soil tests for deficiency

Intercropping

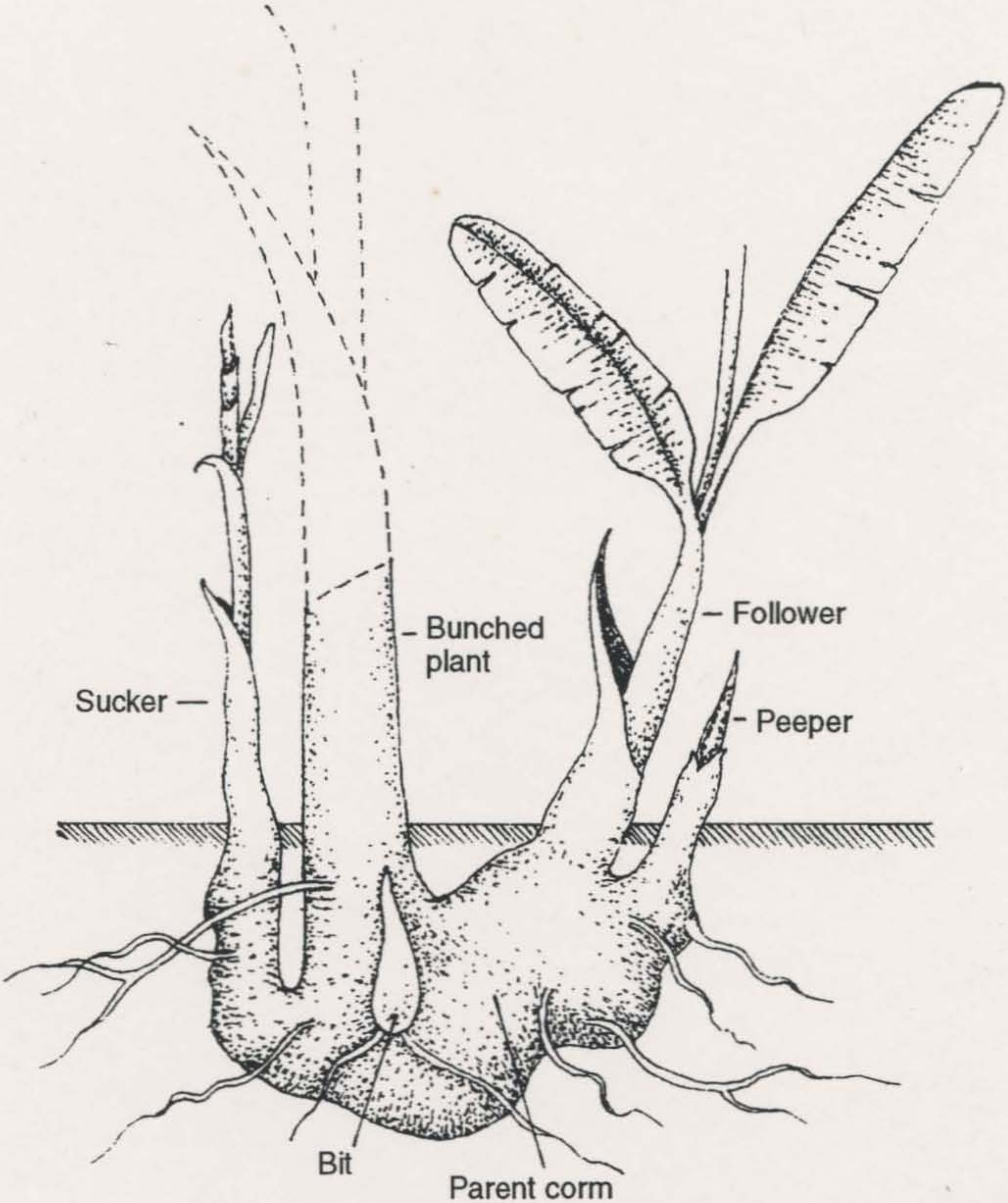
Protein levels of important food crops

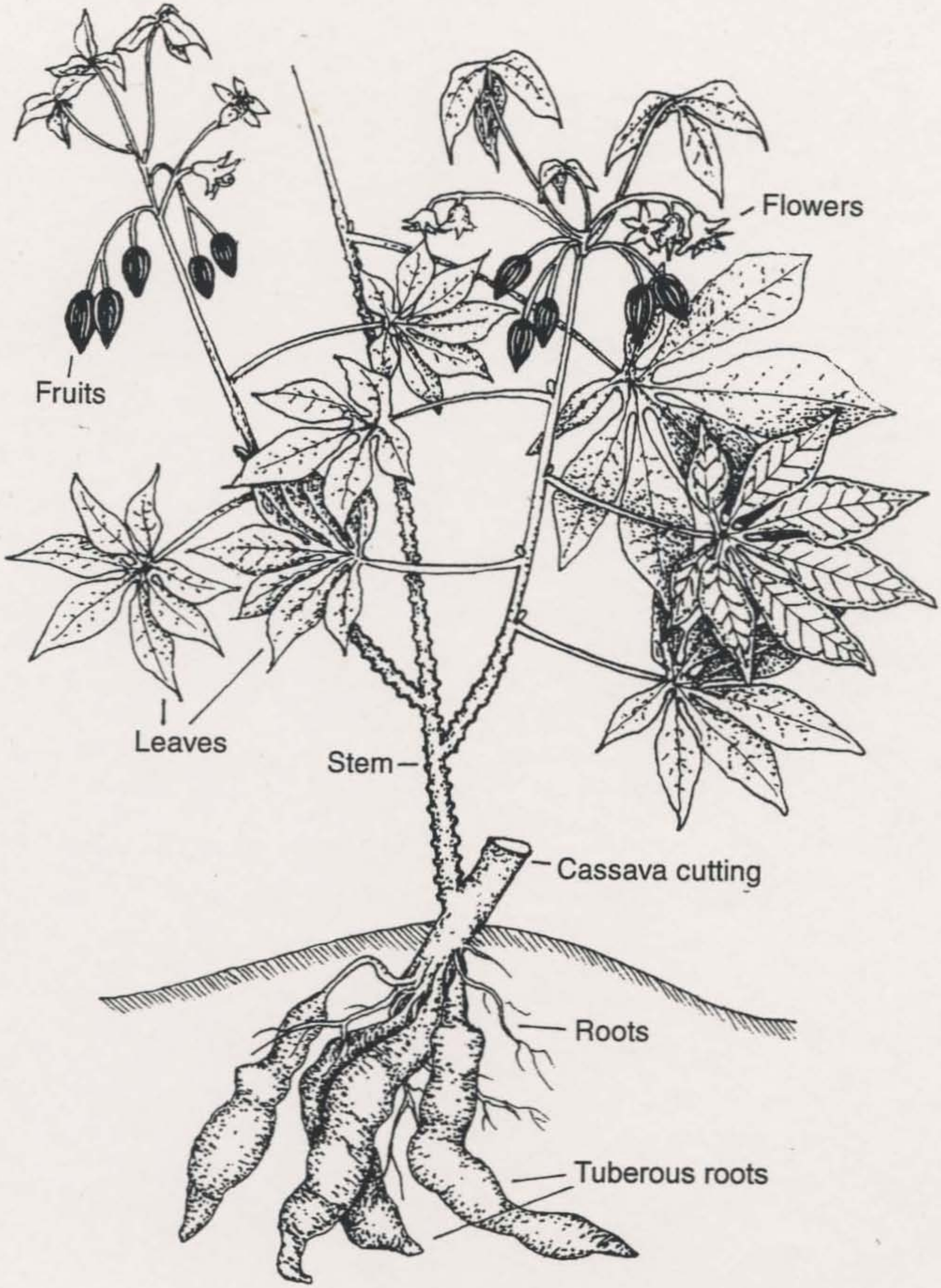
Food Crop	Protein content
Soybean	42% to 33%
Peanut	30% to 25%
Wheat flour	13.5% to 9.8%
Potato	13% to 10%
Corn meal	9.4% to 7.0%
Whole rice	9.0% to 7.5
Polished rice	7.6% to 5.2%
Cassava	1.3% to 1.0%


Apple
Meat
Shell
Air
Husk
Water
Roots
Shoot

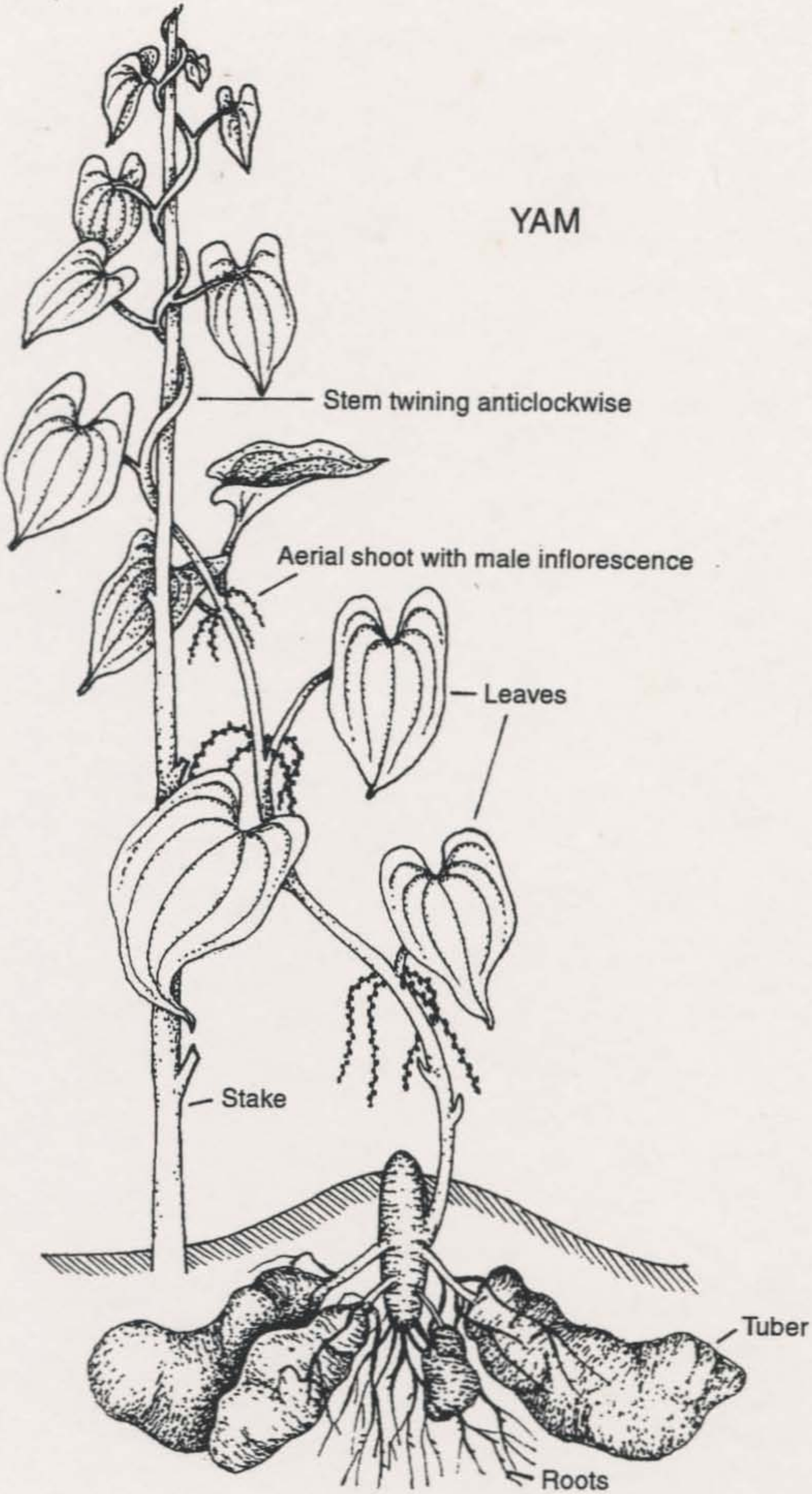


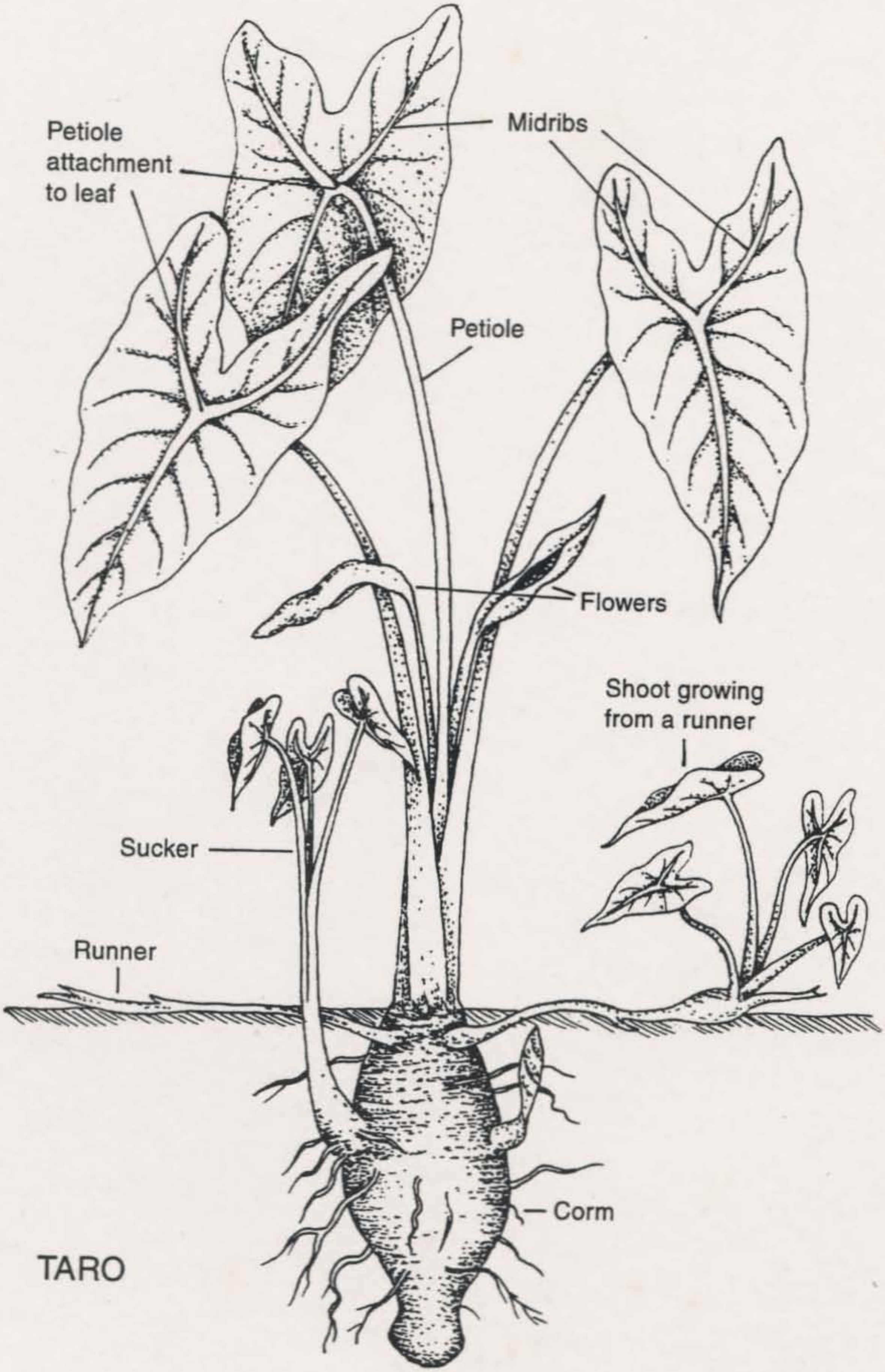
Seven main parts of a banana plant


Bunched
plant
Follower
Sucker
Peeper
Bit
Parent corm

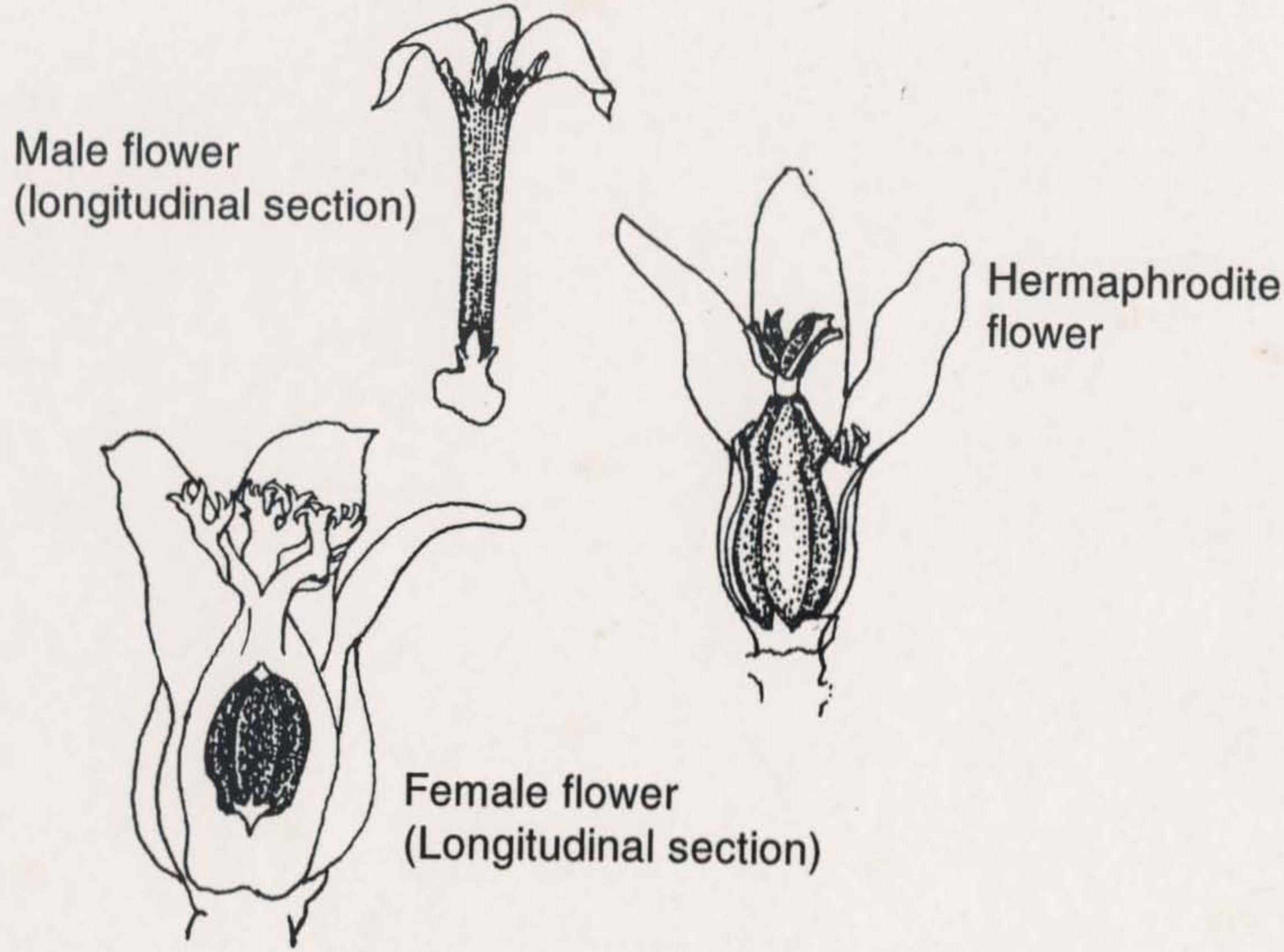

Flowers
Fruits
Leaves
Stem
Cassava cutting
Roots
Tuberous roots

YAM


Stem twining anticlockwise
Aerial shoot with male inflorescence
Leaves
Stake
Tuber
Roots


Petiole
attachment
to leaf
Midribs
Petiole
Flowers
Shoot growing
from a runner
Sucker
Runner
Corm

TARO



Papaya Flowers